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REPORT

ON

BRIDGING THE MISSISSIPPI RIVER

BETWEEN

SAINT PAUL, MINN., AND ST. LOUIS, MO.,

BY

BREVET MAJOR GENERAL G. K. WARREN,

MAJOR OF ENGINEERS.

UNION COLLEGE
SCHENECTADY

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LETTER

FROM

THE CHIEF CLERK OF THE WAR DEPARTMENT,

TRANSMITTING,

In obedience to law, a report of Bvt. Maj. Gen. G. K. Warren, major of engineers, upon the subject of bridging the Mississippi River.

APRIL 29, 1878.—Referred to the Committee on Commerce and ordered to be printed.

WAR DEPARTMENT,
Washington City, April 25, 1878.

The Secretary of War has the honor to transmit to the United States Senate, for the Committee on Commerce, report of Bvt. Maj. Gen. G. K. Warren, major of engineers, upon the subject of bridging the Mississippi River. This report, together with the letter of the Chief of Engineers and accompanying maps, is submitted in compliance with section 4 of the river and harbor act, approved June 23, 1866.

The views and recommendations of General Warren are approved by this department.

In the absence and by direction of the Secretary of War.

H. T. CROSBY,
Chief Clerk.

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., April 25, 1878.

SIR: I beg leave to submit herewith the accompanying copy of the report of Bvt. Maj. Gen. G. K. Warren, major of engineers, upon the subject of bridging the Mississippi River as directed by the following clause of section 4 of the river and harbor act of June 23, 1866:

For examining and reporting upon the subject of constructing railroad bridges across the Mississippi River, between St. Paul, in Minnesota, and St. Louis, in the State of Missouri, upon such plans of construction as will offer the least impediment to the navigation of the river.

The surveys and investigations in the field and the preparation of a map of the valley of the Mississippi were continued in the years 1867, 1868, and 1869, and partial reports thereon were rendered from time to time as were required in special cases.

Numerous other important duties were assigned to General Warren while making this investigation, the most noticeable of which was the design and partial construction of the bridge at Rock Island. Early in 1870 he was detailed to the charge of the United States Lake Survey,

but about this time a serious illness making it necessary, his station was changed to Newport, R. I.

This report was further delayed from a press about this time for reports on special bridge projects, and in 1876 further surveys were found to be necessary on account of the additional bridges that had been built since the surveys of 1869.

For these reasons the preparation of this important report, in suitable form for publication, has only just been completed.

The object of this investigation was to devise a plan of bridging the Mississippi such "that while the railroads could be accommodated the navigation should be preserved," conditions which, adverse in themselves, could only be harmonized and made practicable by reasoning founded upon facts and the teachings of experience. Time was required to bring these conditions suitably together. They involve the most essential facts of observation upon currents at all stages; the record of the rise and fall of the river for a series of years, such as would give a useful mean result; the development of engineering capabilities of bridge-building which, under the stimulus of a greater demand, now accepts as accomplished facts railroad truss-spans of 500 feet, upon piers 100 feet above water, and other developments, such as that of water transportation by fleets of barges propelled and guided by steamboats. All these required the time that has been diligently employed in bringing this new knowledge to bear upon the question to be solved.

When the investigation was authorized in 1866, there was not a railroad bridge authorized by law of the United States upon the Mississippi between Saint Paul and Saint Louis, although one, very obstructive to navigation, had been erected at Rock Island, and another, not quite so much so, at Clinton. At present there are eleven railroad draw-bridges in the same part of the river and several others authorized but not yet built. Probably others will still be desired.

Under the provisions of existing laws, reserving to the United States the right to require an alteration of these bridges when the interests of navigation make it requisite, it is indispensably necessary to have this accurate data at hand that justice may be done in the interest of all parties and the public. This report should, therefore, be published, together with its numerous illustrative diagrams, which can be reproduced by the inexpensive photolithographic process, as the engineering questions cannot be properly considered without them.

These surveys have, together with those previously made, furnished data of much value for the use of the board of engineers upon the construction of sheer-booms for the security of the navigation of the Mississippi River.

Accompanying the report is a general map of the valley of that part of the great river required for the consideration of the subject, which is, in itself, a valuable contribution.

In transmitting this report I desire to express my full concurrence in the views and recommendations of General Warren.

Very respectfully, your obedient servant,

A. A. HUMPHREYS,
Brigadier-General and Chief of Engineers.

Hon. GEO. W. MCCRARY,
Secretary of War.

LETTER OF TRANSMITTAL.

ENGINEER OFFICE UNITED STATES ARMY,
Newport, R. I., March 7, 1878.

GENERAL: I have the honor to present herewith my final report upon the investigation of the question of bridging the Mississippi in such manner as to preserve the navigation, assigned to me under section 4 of the act for the improvement of rivers and harbors, &c., approved June 23, 1866.

Very respectfully,

G. K. WARREN,
Major of Engineers and Bvt. Maj. Gen., U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

REPORT

ON

BRIDGING THE MISSISSIPPI RIVER

BETWEEN

SAINT PAUL, MINN., AND SAINT LOUIS, MO.,

BY

GOUVERNEUR K. WARREN,

MAJOR OF ENGINEERS AND BREVET MAJOR-GENERAL, U. S. ARMY.

1878.

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REPORT.

CHAPTER I.

PREFATORY.

Origin and nature of this investigation. References: To Chapter II, on the formation of the Mississippi Valley and depth to "*bed-rock;*" to Chapter III, a general presentation of Western river-navigation, with discussion of the question of "headway;" to Chapter IV, descriptions of the bridges on the Mississippi; to Chapter V, a history of bridging the navigable Western rivers; to Chapter VI, an account of surveys made, &c.—CONCLUSION RELATIVE TO THE PROPER KIND OF BRIDGE.

Origin and nature of this investigation.—This report was authorized by the following provisions contained in section 4 of the act making appropriations for rivers and harbors and other purposes, approved June 23, 1866:

For examining and reporting upon the subject of constructing railroad bridges across the Mississippi River, between St. Paul, in Minnesota, and St. Louis, in Missouri, upon such plans as will offer the least impediment to the navigation of the river.

Instructions to me from the Chief of Engineers, United States Army, dated August 2, 1866, after assigning other duties to me, say, this "duty is also confided to you, and you will collect all the information pertaining to it."

This enactment in regard to bridging the Mississippi had its origin in a resolution introduced in the Senate (prior to the passage of any act authorizing bridges upon the Mississippi River) by the Hon. Alexander Ramsey, chairman of the Committee on Post-Offices and Post-Roads, and I was instructed to confer with him on my arrival at Saint Paul as one who would furnish me "facilities for procuring much valuable information preliminary to my labors." By him I was furnished with a copy of the debates in Congress on this subject, and taking these as a guide to the nature and extent of the information I was to collect, I probably had a field of investigation more extended than usually falls to an engineer, but in no case have I gone beyond the matters collateral to, if not directly affecting, the strict engineering questions. I have made abstracts of these debates, and give them in Chapter V of this report.

It would be a simple matter to report that a bridge giving about 85 feet clear space above high water with spans of 500 or 600 feet (which, in an engineering point of view, are practicable) would offer no obstruction to navigation on the Upper Mississippi or elsewhere where vessels are propelled by steam and not by sails, and thus meet the requirement of the act; but it is evident from the debates that the "plans" which shall "offer the least impediment to navigation" must be based not merely upon questions of engineering capabilities. These plans must be within limits of practicability as to cost, and be adapted to the place where needed and to the service required of the bridge. The plans must therefore make reasonable provisions for all the requirements of the case, and the presentation must be accompanied by the facts and other evidences of practicability and utility. Such is my view of the duty con-

fided to me, and it seems implied at least in the instructions to "collect all the information appertaining to it."

The passage of several acts authorizing bridges on the Upper Mississippi does not do away with the necessity of this investigation, because the right is reserved by Congress to make such additional legislation as the protection of the navigation may be found to require, and there are some bridges built that are not authorized by Congress which may come before it for consideration and action. Investigation is thus as important for the purposes it was ordered, at the present time, as it was at the outset.

The necessity of bridging the Mississippi was conceded by every one. The only question was as to the kind of bridge, whether to be low ones with draw openings or continuous and of height sufficient to allow vessels to pass under them. The high bridges were advocated by those interested in the navigation, and opposed by those more concerned in crossing the river, as being impracticable on account of cost. The low bottom land banks of the Mississippi River and their great width, the opponents of high bridges said, make the high approaches too expensive. Besides this, the bed of the river was stated to be generally of sand to so great a depth that foundations could not be laid upon the underlying rock, the only secure manner of building such high piers. To furnish definite information on these points was evidently one of the objects of the investigation. The Hon. Alexander Ramsey, mover of the resolution, said on April 30, 1866:

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

is a table giving the areas of the drainage of all the tributaries to the valley above the mouth of the Ohio.

A general presentation of Western river navigation and a discussion of question of headway are given in Chapter III of this report.

The interests of navigation, as represented by the Saint Louis Chamber of Commerce, held that no bridge should be built that did not leave a clear headway over the main navigable channel of at least 50 feet at time of extreme high water. There is reason to believe that the extreme high water referred to was that of the highest known, and not of the ordinary high water; for while it is true that during such very great floods business is generally suspended, yet by placing the bridge 50 feet above that level it gave an increased headway for all ordinary floods and for high stages approaching the level of ordinary floods.

There has been, so far as I know, no thorough discussion of the subject of relative headway at ordinary stages at different places on the Mississippi.

It is obvious enough that 50 feet above extreme high water where the river range is 40 feet and where it is 20 feet is a difference of 10 feet in favor of the first place when the river is at a half stage; that is, there will be 70 feet headway at one place and 60 feet at the other at such time. A different provision in respect to height of high bridges in general seems required.

The United States law authorizing the bridge at Saint Louis, however, provided for a headway of about 50 feet at ordinary high water, which stage is about 7 feet lower than extreme high water of 1844.

The discussion in Chapter III shows (if we provide on the river above Saint Louis for only the ordinary high water) that an elevation of about 57 feet above ordinary high water will be required to give a headway equivalent to that at Saint Louis. This investigation seems to have established the practical rule for all rivers that equivalent headway at different places requires that the height of the bridges measured from the level half way between high and low water should be the same for all places. This is one of the most important contributions to the subject made by this investigation, and it was essential to reaching it that the observations should have extended over the considerable number of years which it has.

A table of rise of water from low to high stages on the Mississippi, Ohio, and Missouri Rivers is given at the end of this chapter.

Lengths of spans.—Experience in the interval of time which has elapsed since the investigation began has settled all questions with regard to the practicability of long spans. At Cincinnati there is a railway bridge with a clear span of 500 feet over the channel of the Ohio. It is of the American pattern of horizontal truss, composed of wrought iron, resting upon piers 100 feet above low water. There is also at Cincinnati a railway truss-bridge with one span of 400 feet. At several places there are railway bridges with spans between 300 and 400 feet, and many spans of railway bridges of 300 feet width in the clear.

At Louisiana, Mo., there is a railway pivot draw-bridge across the Mississippi of 200 feet clear openings, and propositions are now made by competent builders and engineers to employ two such pivot draw-bridges and thus leave one clear opening of 400 feet and two others of 200 feet each side of it.

It must be admitted that engineers can make ample provisions for navigation. Accomplished facts leave this no longer a question.

Description in detail of the bridges on the Mississippi from Saint Paul to

Saint Louis is given in regular order, descending the river, in Chapter IV, which concludes with a list of bridges authorized but not built.

In Chapter V is given a general history of bridging the navigable Western rivers, in its relation to the laws; to the decisions of the United States courts; to the debates in Congress; to the opinions of engineers, &c., arranged in nearly a chronological order. This will be found useful to those having to consider this question in any of these relations. At the end of this chapter is an abstract of the United States laws relative to bridges on the Mississippi, Ohio, and Missouri Rivers. Special attention is asked to the defenseless condition of the navigators before the United States courts, under existing laws, as shown by this history. When the first Rock Island bridge was built the injuries to navigation which followed caused suits of various kinds to be at once brought against it, and an appeal was also made to Congress. A committee appointed by the House of Representatives reported that the courts afforded ample protection. After several years of suffering the navigation interest obtained a decree from the United States district court of Iowa decreeing the removal of part of the bridge. On appeal the United States Supreme Court set this decree aside because of want of jurisdiction in the district court. When the laws were framed in 1866 authorizing bridges, a special section was adopted giving jurisdiction to the district courts. But another section in the laws, making the bridges post-routes, gives absolute protection to the bridges and none to the boats. There have been no suits brought by steamboat-owners against the bridges so authorized. They have to bear the injuries to the vessels, and are liable to suits for the injuries their cargoes sustain and for any damage to the bridge. Something should be done about this.

This report is limited to presenting the Western river navigation and bridges by themselves. From having been a member of boards to consider the question of bridging the navigable channels between the great lakes, I am equally well acquainted with them, but as the vessels there use sails as well as steam, and are otherwise entirely different in construction and management, the principles applicable to one of these navigable waters are inapplicable to the others. The same remark is true of the bridges over estuaries of the Atlantic seaboard.

In Chapter VI is given an account of the surveys and circumstances under which the maps and report have been prepared, with lists and descriptions of all the maps made and the manner of constructing them; also lists of maps obtained from others, and an account of the way in which all have been used in compilation.

CONCLUSION RELATIVE TO THE PROPER KIND OF BRIDGE.

Among a number in Congress in 1856 who yielded to the necessity for passing the act authorizing the construction of the railway draw-bridge at Quincy, Ill., it was felt that although such a bridge was a serious obstruction to navigation, it might be borne if the number of such bridges was small, but that if the number was increased to a dozen their combined obstruction would become insupportable. Not counting draw-bridges authorized but not built, those now in existence have more than reached the limits of aggregate obstruction to navigation that can be borne without suffering great loss. Such bridges "accommodate" the railroads, but the delays they occasion to vessels at night and during winds which do not interfere with the navigation of other parts of the river, prevent a regularity in the running of steamboats and destroy

the systematic arrangements for loading and unloading freights, upon which economical and profitable management depends.

On the contrary, moderately high bridges, allowing the proper headway under them for the passage of pilot-houses of necessary elevation (which, while occasioning some expense and inconvenience in adopting suitable chimneys, when once done, is done for all), can be increased in numbers independently, without materially increasing the obstruction to navigation. Experience has shown that it is practicable to build these high bridges with any needed width of clear spans.

Cheap transportation, the great want of the Mississippi Basin, can only be secured by the barge system, requiring wide openings between the piers, which low draw-bridges cannot give, such as now constructed. Wider openings may be secured by double pivot draw-openings, but as a practical matter it remains to be established.

The conclusion then (which the whole of this investigation and report sustains) is, that high bridges with wide spans are the only kind that will with certainty "accommodate the railroads, and at the same time preserve the navigation."

CHAPTER II.

VALLEY OF THE MINNESOTA RIVER AND OF THE MISSISSIPPI RIVER TO THE JUNCTION OF THE OHIO—ITS ORIGIN CONSIDERED—DEPTH OF THE BED-ROCK.

Definition of the term *valley*—Prominent natural features and length—General maps prepared for publication—Method of considering questions of depth of bed-rock—Explanation of the cause of Lake Pepin and similar lakes—Valley now filling up—Recent drainage of Lake Winnipeg southward—Valley formed since the glaciers began to retire—How the valley was formed—Anomalies of Rock Island Rapids and Des Moines Rapids—Loess formation—Formation of rapids since the Loess—Summary of principal points presented—Explanatory hypotheses—Approximate practical conclusion—Sections of best known parts of valley in regard to depth of bed-rock—Contour map of the sources of the Mississippi—Table of areas of basins drained by the tributaries to the valley.

Definition of the term "valley," prominent natural features and length.—The *valley* to be considered is the part included between the high banks, commonly called bluffs. Whenever it becomes necessary in this report to refer to the whole area drained by the river the word *basin* will be used to designate it.

Between these high banks the greater portion is subject to overflow at time of floods, forming what is sometimes called the *flood plain;* the smaller part above overflow is generally composed of alluvial terraces of sand and gravel. In some cases the distinction between the terraces and the bluffs is difficult to make.

The Mississippi River in its usually navigated parts touches only here and there at places exempt from flood-waters, and these are natural landings for steamboats and sites for towns. In course of time the convenience of the people living there makes them desirable locations for bridges. It is very rare, however, that both banks of the river are above submergeable; where one bank is, the opposite one is generally low, and covered many feet deep at extreme high-water, making it difficult to construct bridges sufficiently elevated for steamboats to pass under them.

The distance along the general course of this valley from Saint Louis to Saint Paul is about 620 miles, but steamboatmen, by the course they take along the navigable channels, make the distance about 800 miles. This was the only part specified in the law authorizing this investiga-

tion, but it was necessary in order to present the subject itself properly to include the whole distance from the mouth of the Minnesota to the Ohio; this is an extent of about 760 miles along the general course of the valley, and we have prepared a map of it in twenty-two sheets on a scale of two inches to a mile. The manner in which this has been done is described in Chapter VI of this report.

General map and profile prepared for publication.—Although we have, in constructing the map, exhausted all means of obtaining knowledge in regard to this part of the Mississippi Valley, there are some parts of it too little determined to make its publication, as a whole, advisable, and therefore we have only prepared for publication the index map of those twenty-two sheets, on a scale of six miles to an inch. (If photographed it may vary from this scale.) Here, again, generalizations have led us to make this index map include the Minnesota River Valley. That valley, under another clause of the law, was also made a part of my investigation, and a map in twenty sheets on a scale of two inches to the mile was made for it. The map submitted for publication is also an index map to those Minnesota Valley sheets now on file at Engineer headquarters in Washington. We have also extended this general map southward so as to include overflowed land as far as the northern part of Arkansas, and northward to include a part of the basin of the Red River of the North. It is designated as Diagram 1, in five sheets.

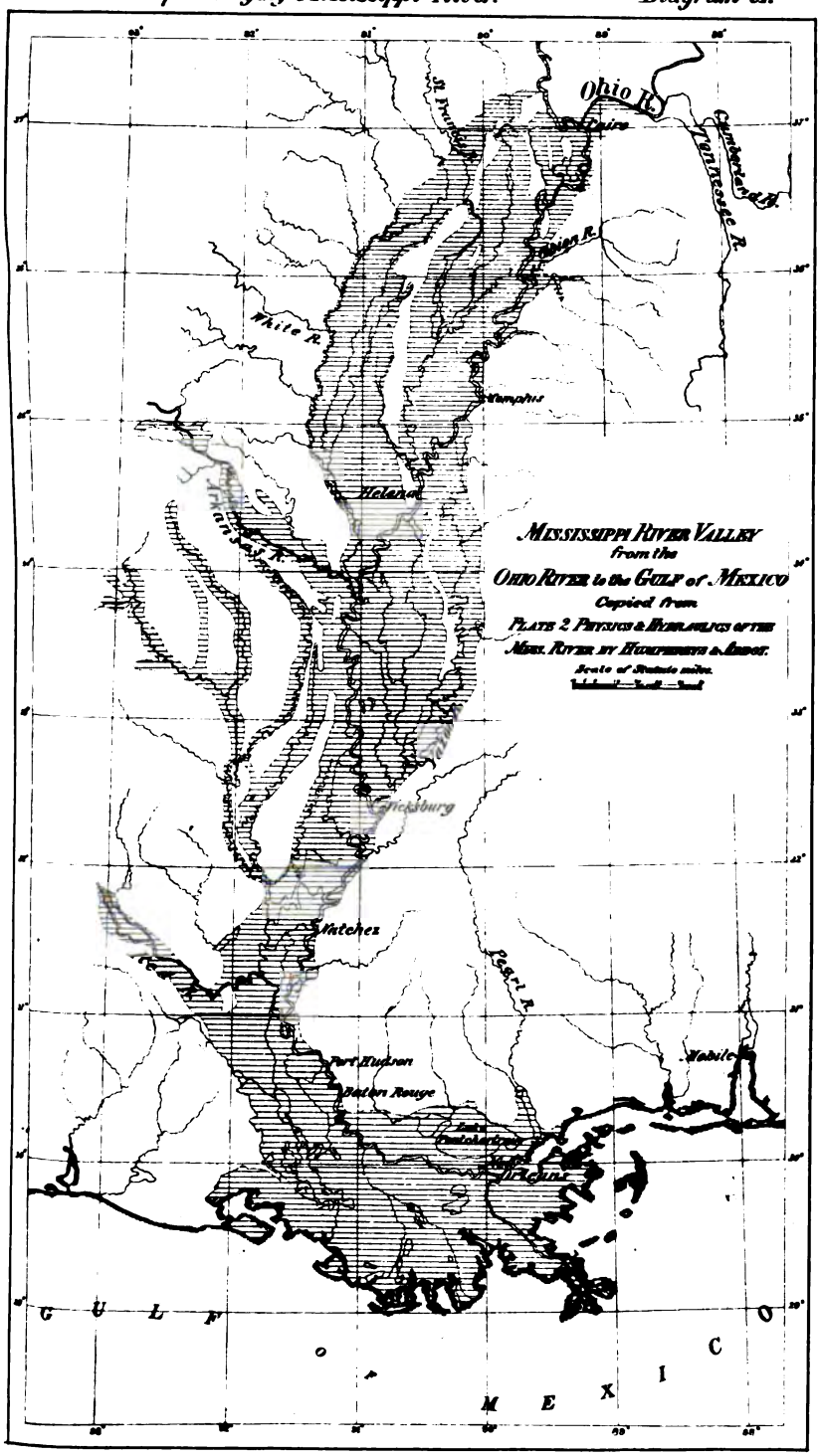
The two systems of United States land surveys are so checked upon each other in its construction and by special surveys by ourselves, that the valley on this small scale is probably as correct as it can be represented. The whole of the flood plain is shaded with light ruled lines, except the principal lakes and water-courses, which are shaded with heavy ruled lines. The alluvial terraces above overflow are shaded with dots. The high banks or bluffs are without shading. On sheet five there are some overflowed lands that are above the Mississippi floods, which have special shading.

In order to complete a presentation of the Mississippi flood-plain to the Gulf of Mexico, the page Diagram A is added, reduced from Plate II of the report of Humphreys and Abbot on the physics and hydraulics of the Mississippi.

General considerations as to the formation of the Mississippi Valley have caused me to present also the page Diagram B, showing the Mississippi basin as it is, and extending northward to include the Lake Winnipeg basin with the ancient extension of the lake southward and outflow through the valley of the Minnesota and Mississippi Rivers.

Profiles prepared for publication.—Accompanying this chapter are two sheets of longitudinal profiles of the valley from the junction of the Minnesota River to the junction of the Ohio. The horizontal scale is about 8 miles to an inch, and the vertical 200 feet to an inch. The datum is the sea-level according to the best determinations, and both sides of the valley are given side by side. The parts of the banks above low water are shaded to indicate the strata of different geological periods, but it must be borne in mind that this low-water line does not represent the low-water slope of the winding river, but is drawn from point to point along the general course of the valley, so as to bring the rocks into their proper relative positions. These longitudinal profiles are designated as Diagram 2, in two sheets.

Another sheet, designated as Diagram 3, gives 20 transverse valley sections, on a larger scale than the profiles: three of them on the Minnesota Valley; one on the Mississippi, above the junction with the Minnesota; fourteen of them in the valley between the Minnesota and



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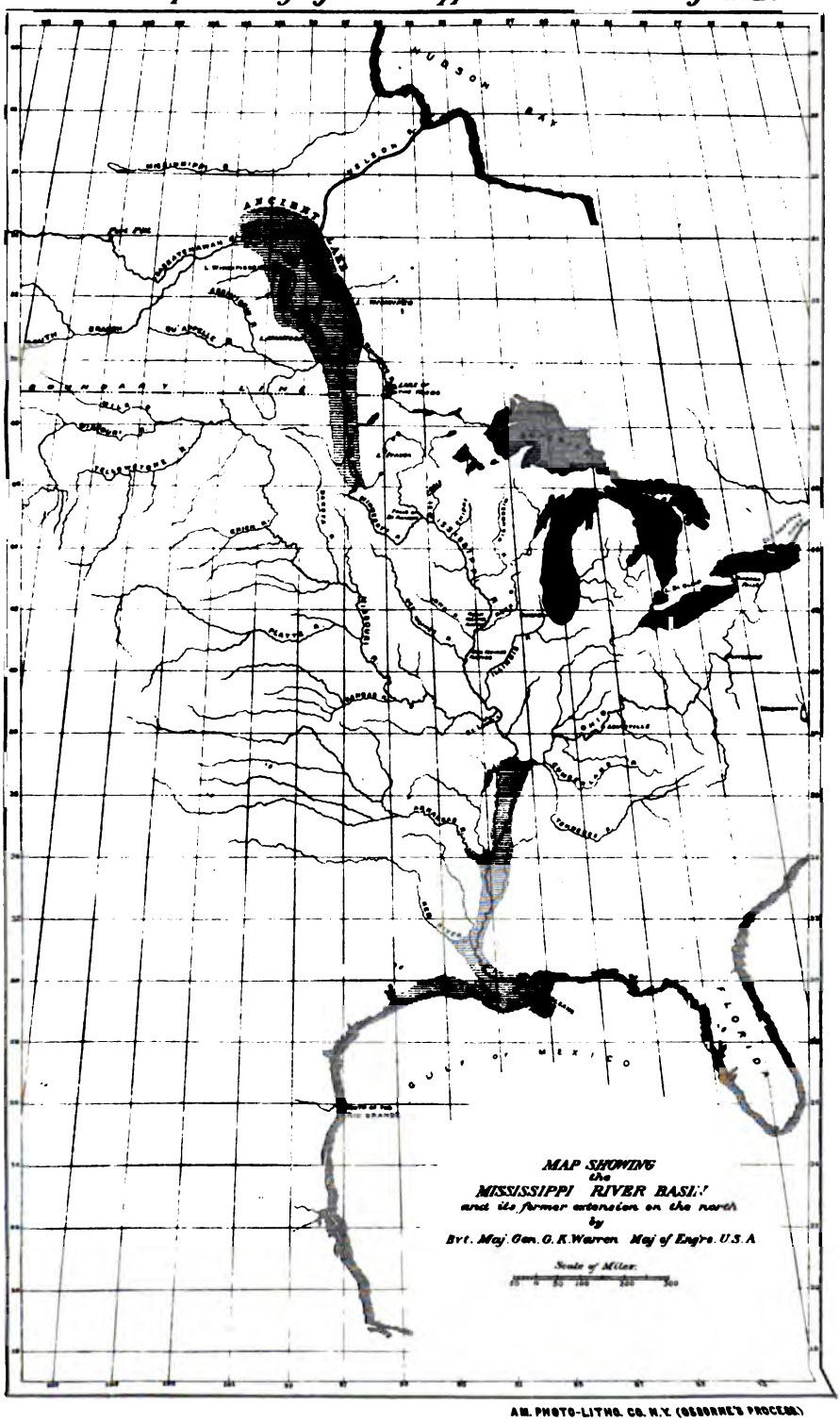
Warren's Report. Bridging Mississippi River. *Diagram B.*



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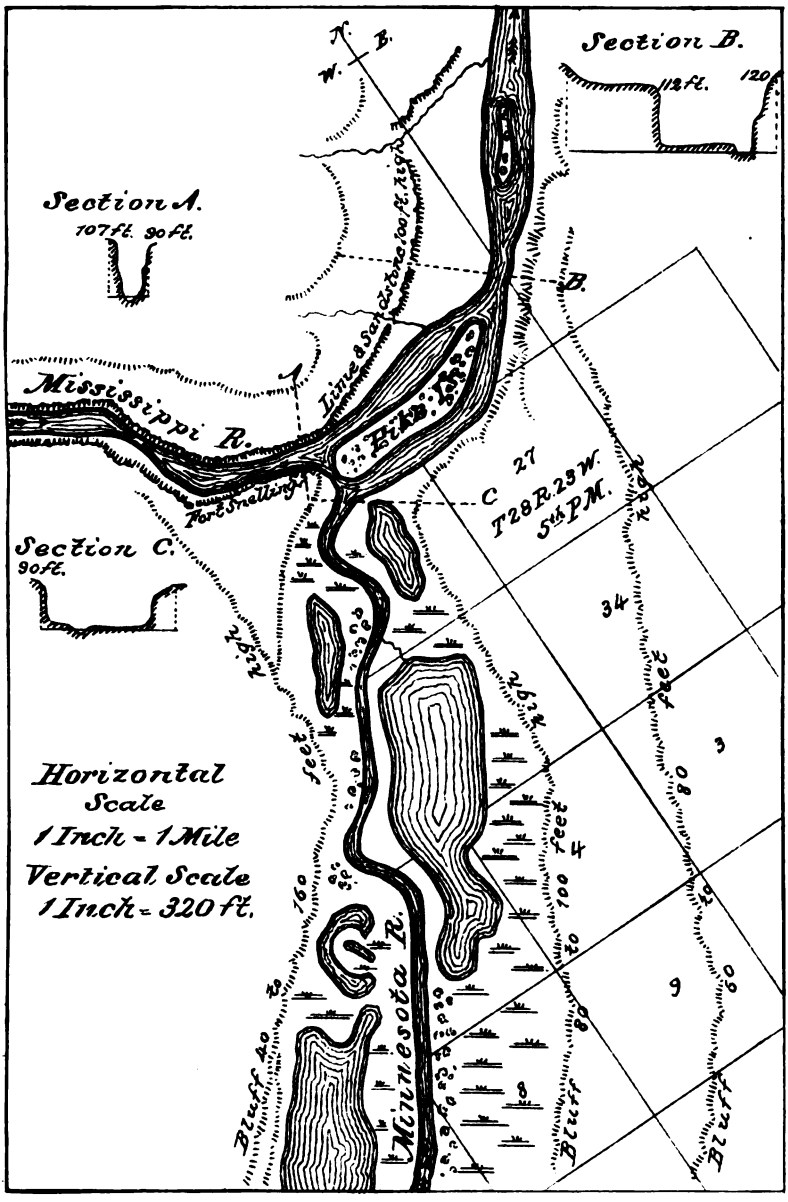
Warren's Rep't. Bridging Miss. R. *Diagram C.*



Map showing the river valley where the Minnesota and Mississippi Rivers join, with sections of the valley below the junction, and on each above the junction.

AM. PHOTO-LITHO. CO N.Y. (OSBORNE'S PROCESS.)

the Ohio; one at the mouth of the Missouri River, and one at the mouth of the Illinois River. These sections are designed to show the extent of our positive knowledge of the depth of the bed-rock, and will be described in detail in the latter part of this chapter.

We are mainly indebted for the geological data in these profiles to the report of David Dale Owen of October, 1851, on the geological survey of Wisconsin, Iowa, and Minnesota; to the report on the geological survey of Iowa, by Prof. James Hall, J. D. Whiting, and Mr. A. H. Worthen, published in 1858, and the report of Mr. A. H. Worthen, director of the geological survey of Illinois, published in 1866.

Method of treating question of depth of bed-rock.—The question of depth of the bed-rock beneath the sand that usually forms the bed of the river will occupy the remainder of this chapter.

In presenting my ideas in regard to it, I have thought the best order in which I could arrange them would be that in which they arose in the progress of the investigation. It was from the first obvious that means and time would not allow of my covering such an extended field by actual borings, and that the most that could be done was to draw such probable inferences as could be done by a study of the rocks visible in the bluffs and by an effort to comprehend the manner in which the valley was formed.

The consideration of the anomaly presented by Lake Pepin lying in the course of the river, and said to have a depth of 60 feet near its lower end, was the beginning of this effort. If the valley in this portion had once been all of this depth, and since filled in, then the bed-rock could not be less than 60 feet below the water surface. Explanations of the cause of this lake had been attempted by Long and by Featherstonhaugh, which did not seem to me satisfactory.

Explanation of the cause of Lake Pepin and similar lakes.—The results of the levelings on the Minnesota and Mississippi rivers made by me showed that just below the entrance of any considerable affluent there was an accumulation of deposit in the main stream brought by the tributary; that over this deposit the slope of the water was greater than the average slope, and that it was shoal and impeded navigation; that just above the affluent the slope was less than the average, and the water deeper. So far, this was in accordance with conditions which generally exist in rivers, and might do so even where the main stream was gradually wearing away and deepening its bed.

But a marked peculiarity was exhibited at the junction of the Minnesota and Mississippi rivers. Regarding the Mississippi as the affluent (which we might do from the comparative sizes of the two valleys), the rule here would be as it is elsewhere, steep slope and shoal water below the affluent and almost no slope and very deep water above. In this instance the effect is felt above for at least 30 miles. On the other hand, taking the Mississippi as the main stream (as the volume of its water has always caused it to be regarded), then we have the anomaly of the main stream filling up the valley and damming back the affluent so that the latter brings no coarse material whatever into the main valley or has any part in forming the shoal below the junction of the two streams.

I called attention to this in my report published in 1867, and again made the anomalous condition a feature in my report on the Minnesota River (An. Rep. Chief of Engineers, 1875, Part I, page 387), where a diagram was given of the streams and valleys at the junction, which I here report as Diagram C. In that report I showed that the valley of the Minnesota River had in the period subsequent to the glacial-drift

epoch been occupied by a much larger river, which had formed the outlet of a great lake, embracing the lake Winnipeg and receiving the drainage of its basin, and extending as far south as the present *Lac Travers* at the source of the Minnesota River. This ancient river, if its volume were as great in proportion to area as that of the Mississippi above the falls of Saint Anthony, probably equaled Niagara in volume, and would have been sufficient to prevent the formation of such excessive accumulation of *débris* in its course, such as the Mississippi is now making below the junction of the Minnesota River, although it is probable that the material brought into it from the near proximity of the falls of Saint Anthony, would have had the usual effect of somewhat increasing the slope and shoalness just below its junction, and decreasing the slope and increasing the average depth just above.

Accepting, then, the conclusion which I have elsewhere made reasonable, that the drainage of the Winnipeg basin was formerly along the Minnesota and Mississippi below the junction, then when the flow of water from that great northern basin ceased there would no longer be the volume of water necessary to remove the deposits brought by the affluents into a channel of too great capacity for the requirements of the new conditions.

In building the railroad bridge across the mouth of the Minnesota, Mr. Shepard, the engineer, made borings to ascertain the character of the foundations. A rod was forced down about 60 feet, at which distance a stratum was reached so yielding that the rod's weight would be barely supported. He did not endeavor to probe further, for just before reaching this soft layer he passed through a harder one of sufficient thickness and resistance to support his structure. This bridge is a work of minor character. This shows that the deposit in the old valley exceeds 60 feet at this point. The Minnesota being a muddy stream, its fine silt has much filled the lake which the Mississippi *débris* at its mouth caused.

The *débris* and material brought over and from the Falls of Saint Anthony has been carried downward by the water, gradually accumulating and filling the valley as it advanced. One should here stop and consider the manner in which river deposits are made. The finest clay is so easily mingled with the water that the slightest disturbance in the fluid as it moves even with the gentle currents, is sufficient to keep it from settling down until the still water is reached. The amount of this on the Upper Mississippi is comparatively very small. Such materials as can be moved only by the swiftest currents are rolled over along the bottom, gradually diminishing in size by friction, and furnishing smaller particles susceptible of being thus moved by feebler currents. The resulting material is pebbles, gravel, and sand, the fine material, such as clay and vegetable matter, being all washed out.

When deposits of gravel or sand are made of materials moved along the bottom, it takes place as soon as the current slackens, as it must do on reaching a place having larger sectional area. The deposit is sudden, and the material is all taken up in diminishing the section, until the velocity of transportation is restored; then deposition continues immediately in front of the last deposit. Such deposition, therefore, does not extend laterally from the course of the current into any contiguous dead water, as depositions from water holding a clayey or vegetable matter would.

Thus in the valley of the Mississippi, the lakes alongside the river's course are deeper than the river, which has continued to raise its bed by deposits of sand after the lakes were cut off from its current.

From the Falls of Saint Anthony down to the Saint Croix River the Mississippi Valley receives no considerable tributary. The Saint Croix comes from a region of trap rock now furnishing little or no large and heavy sedimentary matter. The result has been that the Mississippi's deposit of sand and gravel has been thrown across its mouth, holding back its water and forming the Saint Croix Lake. At low water, while the depth of the Mississippi at the juncture is 2½ feet, the depth in Lake Saint Croix is 25 feet. It is not probable that 25 feet depth represents the amount of filling of the ancient valley at this point, because the lake itself must have been somewhat shoaled with fine deposits of clay and vegetable matter.

The next considerable tributary to the Mississippi Valley is the Chippewa. This, entering at right angles with a steep river slope and a probable high-water volume of at least 40,000 cubic feet per second, comes from a region inexhaustibly supplied with siliceous sand and gravel containing a considerable of the heavy magnetic sand, whose oxidation often cements the other sand deposits.* It brings quantities of these materials, which spread out below, give a very steep slope to the Mississippi River and very bad shoals for navigation.

Lying just above this deposit is Lake Pepin, which it completely accounts for. The reason this lake has not been filled up by the Mississippi above is that the supply of sand from the Chippewa is so great as to raise the level more rapidly than the filling above can keep pace with. The Chippewa from the left bank pushes its sand-bar out, so as to confine the outlet to the lake to the opposite shore. There is an observable relation between the condition of the lake and the deposits of the Chippewa. The deepening of the waters by the deposit of Chippewa sands is felt at low water sometimes as far up as the mouth of the Saint Croix, when floods in the Chippewa make these deposits large, and on the other hand, in times of droughts the waters of the lake cut the outlet deeper, and lower its level, so that the shoal water is moved down the river two or three miles below the Saint Croix.

If we follow the Mississippi down we find similar conditions produced by the Wisconsin River as by the Chippewa; that is, a great increase of the slope and shoaling of the river below the junction, with gentler slopes, deep water, and lake-like aspect above. There would probably have been a large lake here if the discharge of Black River, just above, had not silted it up.

Another instance is afforded by the damming-back effect of the Mississippi deposit at the mouth of the Illinois River, making it at low water almost like a lake up to La Salle.

Lake Pepin must therefore be regarded as due to the deposit by the Chippewa of heavy coarse sediment into the valley of an ancient and larger river. This view may be strengthened further by the following considerations: It lies immediately in the course of the main valley above an important tributary. In this respect it agrees with Lac-qui-parle, on the Minnesota, just above the Lac-qui-parle River; with another lake on the same valley just above the Yellow Earth River; with Big Stone Lake in the same valley, just above Whetstone River; with Lake Traverse, which is formed by deposits from a stream at each end, and this empties sometimes in both directions. It agrees in this relation

* The analysis of the soil on this part of the Chippewa River (the Yellow Banks) gives 93 per cent. of insoluble matter, which is chiefly white sand, with only 2 per cent. of organic matter, less than 4 per cent. of soluble saline matter, consisting chiefly of oxide of iron and alumina with only a trace of calcareous earth.—(Owen's Report, p. 56.)

with the lakes on the Qui-Appellee, which all lie just above a considerble tributary, and with like lakes on the Upper Fox of Lake Winnebago. This constant relation seems unmistakably one of cause and effect.

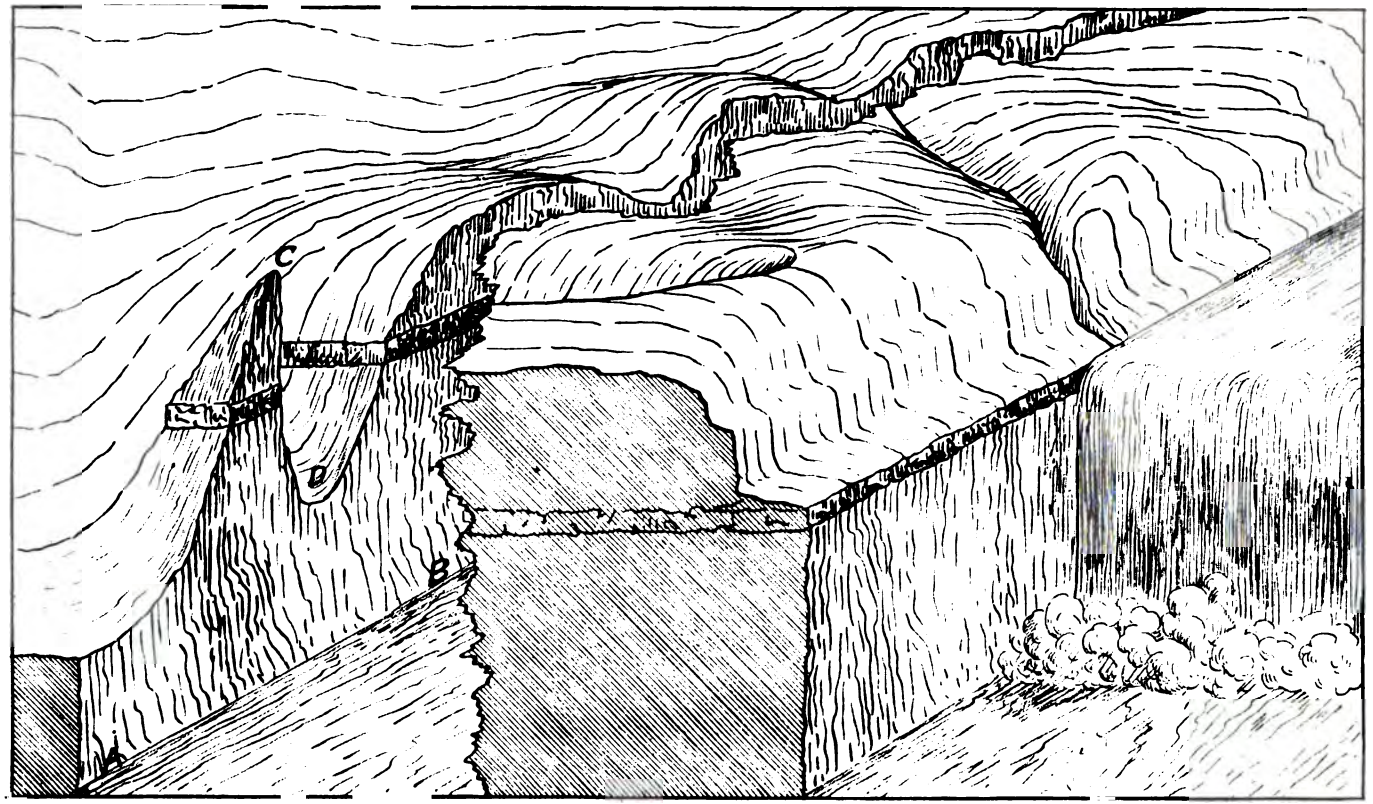
Valley now filling up.—From what has been stated above, it is clear hat the river valley in the part we have considered is not now being deepened by erosions, but, on the contrary, is filling up, and it appears to be doing so all along its lower course except at the rapids.

Recent drainage of Lake Winnipeg southward.—As I have stated in previous reports, I regard the ancient river draining the Winnipeg southward by the Minnesota and Mississippi Valley as existing subsequent to the glacial deposits. This is based upon the fact that the river's course is cut through those deposits, as shown by the banks in many places from Lake Traverse, in Minnesota, to Warsaw, in Illinois, and that the ancient bed of Lake Winnipeg is free from glacial deposits, and exhibits only the silt-deposit since made by the ancient lake itself.

Valley formed since the glaciers began to retire.—It also seems most probable that the ancient valley itself, as a whole, was formed in the region of glacial deposits, partly during the period this great field of ice was receding, and partly since it left the ancient Mississippi basin, for the following reasons: When this ice-period was on the increase, its southern margin must have been gradually advancing in this region, crushing down and planing off the ridges and filling the ravines and water-courses with the *débris* not only of the neighboring rocks, but with the great mass of hard rocks and other material brought from regions far to the north. There seems a probability that much of the present Upper Mississippi basin had previously been for long ages exposed only to erosions of streams and of the atmosphere, so that it was probably much cut up and fissured, as we see in regions farther west, where no glacial action has occurred. It must have been an easy matter then for the glacier to have thoroughly filled up all the valleys and ravines, leaving the surface everywhere of the well-known rounded hill and basin forms of the drift regions. Wherever the glacial scratchings are preserved, their uniform directions indicate a massive movement to the southwest quite independent of all influence of underlying inequalities. The water which flowed from them would seek the the first lowest line and excavate its course without regard to the nature of the older stratified rocks buried beneath the glacial deposits, and such seems to have been the case, for the valley takes a great variety of courses, running about northward at Saint Paul, due west at Rock Island, and its directions fill every azimuth in different parts from northeast around by south to west. To the old stratified rocks its course seems to have no relation, now cutting across an anticlinal, then following the strike in one direction and again in the opposite one.

How the valley was formed.—At Saint Paul, on the Mississippi, and in the Minnesota above, are the banks of an ancient water-course when at such higher level than now that the river-bed was the magnesian limestone rock, the same as that of the Mississippi, just above the Falls of Saint Anthony. The existing channel of the ancient valley has probably been formed by a cataract in the great river, similar to that at Saint Anthony. This river is sustained by the high islands of rock in the valley of the Minnesota, being remains of strata once continuous across it. These high islands also exist below in the Mississippi, such as Barn Bluff, at the head of Lake Pepin, and the Trempeleau hills. Some of these detached bluffs may have been formed by bends approaching each other by erosions gradually forming a neck and cutting it off. One such, nearly completed, is seen in the Dalles of the Chippewa River. The

Warren's Rep't. Bridging Miss. R. *Diagram D.*



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period which must have elapsed in doing this work was large, but it is probable that the volume of water, during the melting of the glaciers north of it, was greatly in excess over that of the present drainage of the Winnipeg basin. The period may have been somewhat shortened by the new water-course regaining in places some ancient one, filled only with glacial *débris*.

If we look at the valley shown on the map from Lake Traverse to Rock Island, we see that it gradually widens and contracts along its course, but, as a whole, widens as we descend. It widens where the rocks on the banks are soft, and narrows where they are harder and capable of resisting atmospheric erosion, as they are near Dubuque. This is in accordance with usually received ideas, that where the stream is confined by hard banks its increased velocity, due to such contractions, may have caused the streams to abrade deeper. It is improbable that the ancient river, where it cut its way either as a cataract or in any other manner of river erosion, made the valley as wide as we now see it. It most probably underwent subsequent widening from the impinging of the currents against the foot of the high banks, thus removing the *débris* falling from the cliffs above, as well as scouring away the unbroken strata against which it washed. Even now, although the great river has disappeared, we see that the valley is still widening in some places where the river flows at the foot of the high bluffs, although, in the great majority of cases, the atmospheric erosions have covered the steep, rocky scarps with detritus, which, clothed with vegetation, preserves them from the influence of the air. Where the river now impinges against the banks composed of soft strata, we sometimes still see its effect in the fresh-cut appearance of the cliff, and are led to give greater weight to similar operations in the past, when like forces were probably more intense.

I have selected one (Diagram D) such cliff in the wide part of the valley below La Crosse, which part indicates much widening since the first cutting out of the river's course. It is apparent that no stream of water could have cut down from C to A B while the opening D was available. But if we allow that cataract on the right of the diagram represents the conditions when the stream began to flow which cut the valley, then its present course is natural, the subsequent widening bringing it to the state we see on the left of the diagram.

Geologists of high character have estimated the age of the gorge at Niagara Falls on the present rates of recession, and, though the result is uncertain, it indicates the origin to be in recent geological times, although antedating the historical era. In a similar way the time required by the Mississippi to cut the gorge from Fort Snelling to the Falls of Saint Anthony has been calculated by Prof. N. H. Winchell (Report Geological Survey Minnesota, 1876), on data that makes it vary from 6,000 to 12,000 years, by assuming that the forces in producing this result have remained uniform during this period.

That any date in geological time, capable of being expressed in definite numbers of years, can be deduced from existing observations seems highly improbable; but whenever a condition is observed which may be referred properly to the operation of causes now at work, whether of greater intensity or less, it is reasonable to regard the work done as of recent geological origin. We cannot neglect this uncertain method of drawing inferences, since it is the best we have, and we should endeavor, by continued investigation, to make more definite this method of finding the unknown factor, time.

Since the Falls of Saint Anthony were at the junction of Minnesota

Creek, they have receded 6¼ miles. The Minnehaha Falls, since that time, have receded three-fifths of a mile. Both streams have cut into the same formation, starting with the same height of fall. These relative rates have been about as 1 to 10. The proportion of the volumes of the two streams, judging by their present drainage areas, is about as 72 square miles is to 21,600 square miles, or about as 1 to 300. That is to say, the recession of the Minnehaha Falls has been thirty times faster than it would have been if proportionate to the volume. This may be accounted for by the greater atmospheric influence at the smaller falls, which, examination shows, keeps ahead of the effect of the water, forming a cave under the fall by the dropping down of material which the water then washes away. At the greater falls the volume of water almost constantly protects the rocks from the action of the atmosphere. Hence we must give, as said before, a very considerable influence to the operations of the atmosphere in aiding the erosions of small streams, and in demolishing cliffs where the water can remove the *débris*.

I attribute a more recent origin of the gorge of the Mississippi from Fort Snelling to the Falls of Saint Anthony than to that of the Minnesota above the junction. The general map indicates that the same force which formed the valley below the junction formed that of the Minnesota above.

The hypothesis which I have heretofore advanced and endeavored to sustain, that the loss of the Winnipeg outlet along the Minnesota was due to a change of the continental slopes by a northeasterly depression, will explain this more recent origin of the Saint Anthony Falls gorge. This supposed change of slope might have caused a change of outlet of the lakes about the present source of the Mississippi, so that the waters flowed out on the northeast and, falling into a depression leading southward, made this upper part of the Mississippi. When we note the great extent of the eroded valley of the Minnesota, and also the fact that all the smaller streams, like the Saint Croix, Chippewa, Black, and Wisconsin, have cut through the sedimentary rock down to the granitic or trap rocks, it seems improbable that the Mississippi above Fort Snelling, with its greater power, should not have accomplished as much if it had been as long at work.

Regarding the Mississippi Valley as originating as a whole by the action of a stream since the glacial ice occupied its basin, I would note that as far down as the island of Rock Island there is no decided indication of other than successive changes attending such action, and the gradual filling up of the valley by tributary sediment after the great volume of water from the Winnipeg basin had disappeared.

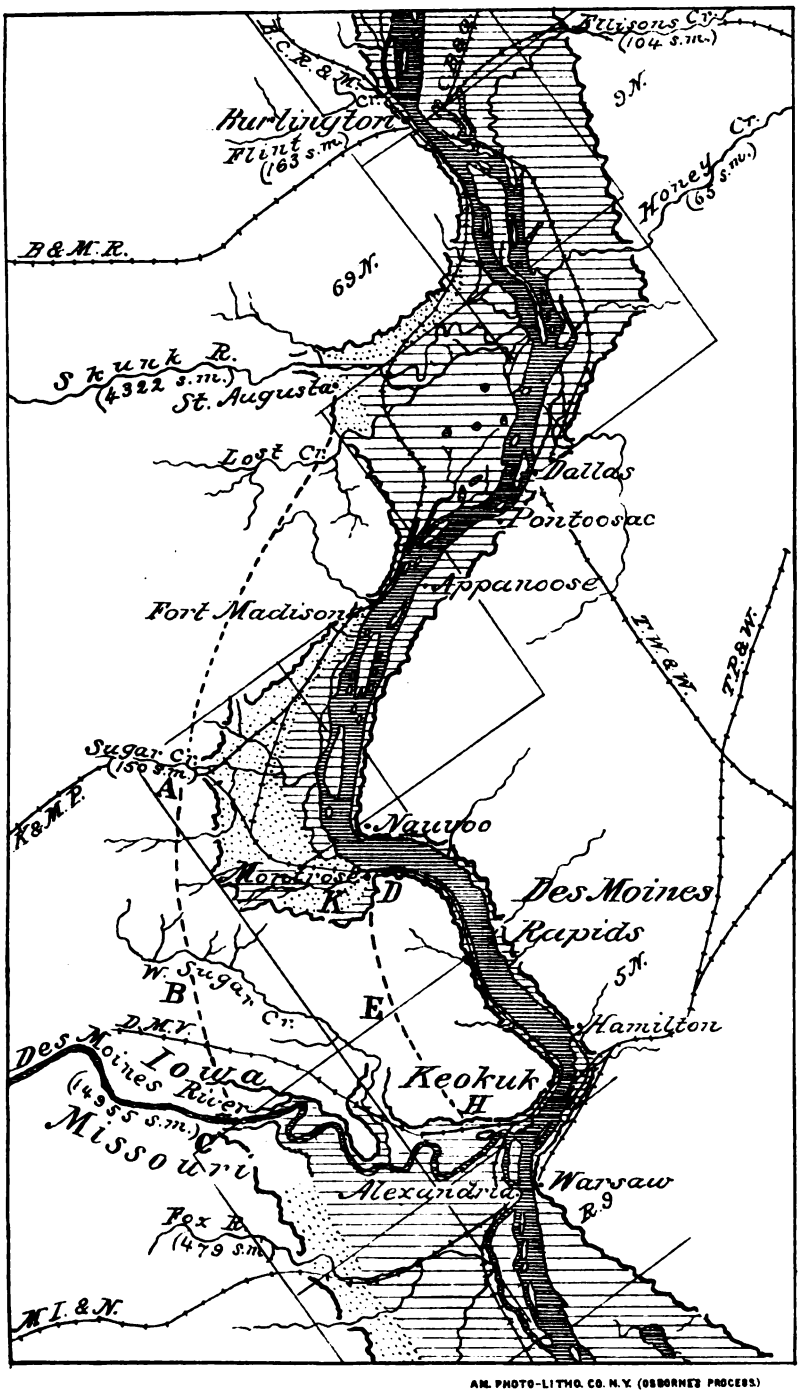
Anomalies of Rock Island Rapids and Des Moines Rapids.—At Rock Island the river has left the ancient valley, and below Rock River seems lost. We might have supposed that it ended here but for finding it again below Muscatine and continuous down to the Des Moines Rapids, where it is lost again. Just below, however, we find it again, and it then is continuous until it widens out into the broad expanse below the junction of the Ohio, although the river again leaves the main valley, without sufficient apparent cause, at Fountain Bluff and at the Grand Chain.

We had not time to study out where the course of the ancient valley was between Rock Island and Muscatine, but at the Des Moines Rapids we were more fortunate.

The following description of this vicinity and Diagram E will present the points that appear deserving of consideration.

The river, as it passes the town of Madison on its right bank, which

Warren's Rep't. Bridging Miss. R. *Diagram E.*



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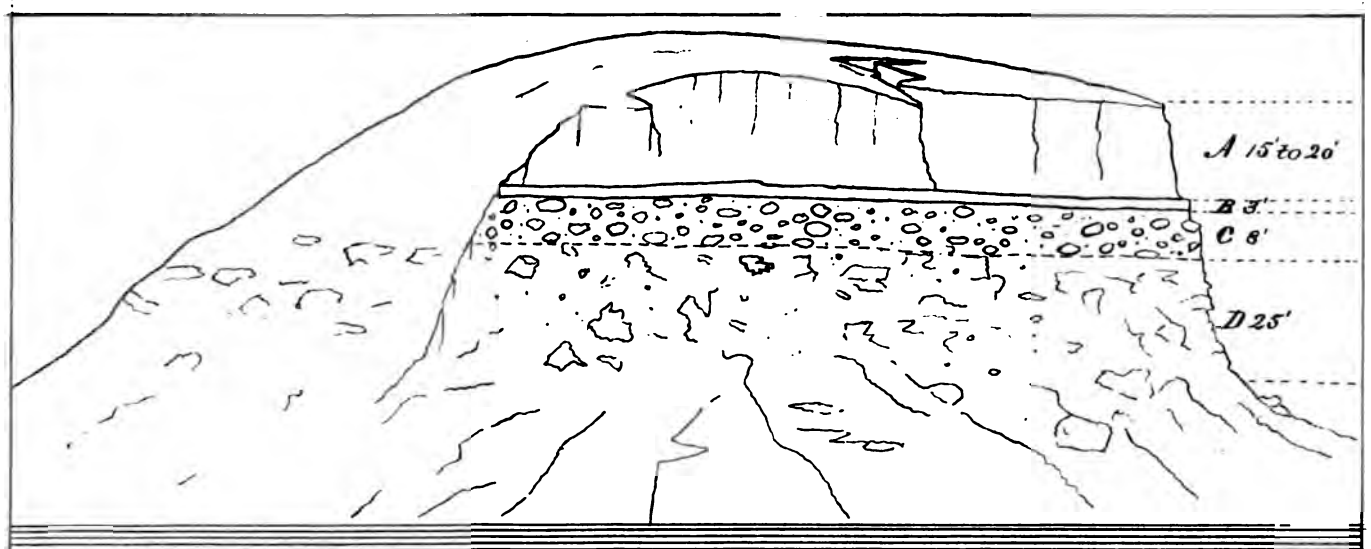
Warren's Rep't. Bridging Miss. R. *Diagram F.*



Section of Mississippi River Bluffs at Warsaw Illinois

A is a very fine yellow sand and clay widely developed. B is a bluish clay and fine sand C is rounded hard bowlders from small gravel up to 400 lbs., mixed with sand. D is composed of angular blocks from over a ton weight down to small stones, mingled without order; with coarse and fine sand and clay, showing no selection or sorting. The rocks are trap, porphyry, granite gneiss or syenite, hard brecciated limestone &c. The upper carboniferous shales in vicinity exhibit local displacements

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is there 150 feet high, washes against a bluff composed of clay and sand arranged in a manner resembling "the ebb and flow structure." Mr. Worthen gives a good description of this formation in the Iowa Geological Report, vol. 1, part 1, page 187. This kind of bluff is seen only on the right bank, and extends continuously a distance of about 25 miles from the mouth of Skunk River down to the point D (see Diagram E), where it joins the Keokuk limestone rock just back of Montrose.

In descending the river from Madison, the river gradually recedes from this bluff; and a few miles above where Diagram E begins the bluff is 3 miles from the river. A large portion of the intervening space is occupied by a sand terrace, varying from 20 to 50 feet in height above the high water; the other portion is bottom land, subject to overflow.

The river, before reaching Montrose, has a width within its banks at ordinary stages of about half a mile, and the depth of water in the pools at low stage is from 15 to 20 feet, the bed being of sand, with no rock in place; nor is there any rock in the right-bank bluffs till just below Montrose, where it begins also in the river-bed. On the left bank or Illinois side the bluffs are of rock, the same as at the rapids, where they have been cut through by the river. This cut begins at Montrose, where the river makes a turn at a right angle to the eastward, but the depth at low water is only 2 to 3 feet, and the width at ordinary stages has widened to 1 mile. On both sides of the rapids the rock bluffs rise almost immediately from the water. The river on the rapids continues easterly about 2 miles, then turns southward and maintains this direction until all the rapids are passed and for a mile beyond; then turns southwest until the mouth of the Des Moines River is passed, and then turns southward again.

The rock disappears on the bed in passing Keokuk; the water then deepens, flowing on a sandy bed, and resumes its width of about half a mile between its ordinary banks. On the rapids there are no considerable or permanent islands, but as you go above or below, you find them as soon as the rock-bed is left.

At Warsaw, 3 miles below the foot of the rapids, the Carboniferous rocks show in the bluffs, and so does the unmodified glacial drift, covered with the loess. (See Diagram F.)

The Mississippi Valley at Warsaw is about 8 miles wide; part of it a sand terrace, but most of it subject to overflow.

Proceeding up the Des Moines from the mouth, we leave the limestone strata at the point H (Diagram E), and do not meet with it again, either in the river-bed or bluffs, till we reach the point C, where we find it in both places, and thence all along up this valley.

In this distance between H and C the bluffs are only on the left bank or north side, and the material appears similar to that at Madison or to the loess at Warsaw, shown in Diagram F. If we examine the valley of Sugar Creek, we find the bluffs cut down as low as on the Des Moines between H and C, and all of similar material, clay and sand, but no rock in place. Nor could we find on any of the branches between A B C and D E H any rock in place or learn of any. Within these limiting lines those who have dug wells for water find it without reaching rock.

At the place marked K on the sand terrace a well 50 feet deep encountered no rock, although this was as far down as the level of low water in the river.

The width of the main valley above Fort Madison is nearly the same as below Keokuk, and if we prolong the line of bluff between these two places, it will include a space between them where there is no known

rock *in situ*, and which it appears reasonable represents the ancient channel, since filled up.

The loess formation.—This name has been given in this country to a fine material deposited over all the other formations, including the glacial deposits near the river, but not upon the river sand-and-gravel terraces, which are therefore the more recent. It has a thickness of many feet in places. It is generally regarded as having been deposited in quiet water. In many places it is nearly uniform in thickness, conforming with the previous irregularities of the surface, as snow lies where it has not drifted. This would be brought about by a silt-laden fresh-water current spreading out over one more dense and quiet, through which the fine silt dropped. Such conditions would exist in salt water, and the silt would prevent the existence of many kinds of marine life, and would contain the animal remains brought from the fresh-water streams.

The margins of the loess deposit are not well defined, and do not appear to have been investigated as they should be. The deposit is well shown near Rock Island, but does not appear as high up as Dubuque (so far as I know). It extends up the Missouri as far as Sioux City, and the Missouri River made immense deposits into the body of water in which the loess was laid down. From the absence of marine fossils, this body of water has been regarded as fresh and without connection with the Gulf of Mexico except through an outlet. Judging from what I know of the deposits, I should think it did not connect with our present Great Lakes, and that a tongue of land or promontory separated the arms extending up the Mississippi and Missouri rivers.

The extremes which brought this fine loess material which has been so spread out must have brought down heavier material along the bottom that fell as soon as it reached the enlarged section, just as rivers make their deposits of heavy material now on reaching their natural receptacles. A most interesting case in point is in the deposits made in the Great Salt Lake in quarternary times, where its terraces show a level nearly a thousand feet above its present surface. The streams, like the Weber, built out the terrace at their point of discharge in the fan shape of a river-bar up this terrace level near the ancient shore, and extending back in the river valley, which must then have appeared as a fiord. Although the ancient Weber River deposit diminished in amount as it extended into the ancient lake, it yet terminated quite abruptly. I think, then, there is good reason to regard the bluff-deposits at Fort Madison and vicinity, on the west side of the valley, as belonging to the loess period, and not to glacial times. These deposits are where streams would bring them from the northwest, while the glacial deposits seem to have come from the northeast. This filling up of the ancient valley of Keokuk and Madison, and also in the neighborhood of Rock Island, is where the mouths of considerable rivers probably were during the existence of the large body of water in which the deposition of the loess was made.

Formation of rapids since the Loess.—Where the body of water of the loess period disappeared and the emergencies of the land again took place, the Mississippi did not regain its ancient channel, but cut the new one now occupied. These rapids cannot be accounted for by any special hardness of the rocks, but their resistance is increased because of the dip of the strata being nearly that of the river-slope. When the river was at a higher level and made the sweeping bend above Montrose so as to wash the loess bluffs, but little more erosion would have been required there to have carried the river back again to its ancient channel during some extraordinary flood, and yet it might have been

that the new channel would even after this remain the permanent one for ordinary stages.

Such an explanation as this may be applicable to the cases at Fountain Bluff and at the Grand Chain on the Mississippi just above the mouth of the Ohio, and to the almost incomprehensible changes of course in the lower Ohio itself, shown on the general map.

Another interesting supposition may be made that the Mississippi in the last terrace period should have succeeded in washing down the bluffs, separating it near Burlington from the Crooked Creek flowing into the Illinois. (See Diagram 1, sheet 4.) The new channel would have double the descent to the mouth of the Illinois of the existing one, and we might have gained a new course for the river, leaving a larger ancient channel occupied by a smaller stream, and there would have been set at work a new cause to modify all the valley of the Illinois River and all the Mississippi above.

Summary of principal points presented.—I will summarize the principal facts that seem to be made out along the course of the Minnesota and Mississippi:

1. That the Minnesota Valley and the Mississippi Valley above the Ohio have been, as a rule, formed since the deposition of the glacial drift, for this exists in unmodified and modified forms in the banks of the river, and that the Winnipeg basin drained out southward along it.

2. That the loess deposits, extending up to the neighborhood of Savannah, are later than the last glacial drift.

3. That channels like those at the Des Moines Rapids and river terraces in that vicinity are more recent than the loess.

Explanatory hypotheses.—I have advanced this hypothesis of alternate southern elevation and northern depression several times before and illustrated its effect on the Minnesota and on the Wisconsin River, and in the first instance considered what the results would be in contiguous regions, and how far facts seemed to correspond, so it will be unnecessary to repeat them here.

The hypothesis appears to be in accordance with a number of very important facts, and is consistent with observations as to southern elevation and northern depression now going on. It explains, by one widely exerted influence, many effects which, on the grounds of glacial action alone, requires many special glaciers, and it will answer as an explanation of the coming on and disappearance of the loess body of water, and for the change in the drainage of Lake Winnipeg. If we can show that any movement of the earth's crust is a recurrent phenomena it may help us to trace out its cause.

Approximate practical conclusions.—The only conclusion which can be drawn from the preceding discussion seems to be that the origin of the excavation of the valley is comparatively modern, and that it was from the operation of forces producing probably uniform results, and in a way that we have some approximate comprehension of it in general, from our knowledge of special localities.

Sections of best known parts of the valley in regard to depth of bed-rock.—The following-described transverse sections of the main valley with three taken across tributaries just above their junction with it give all the positive data we have in regard to depths to bed-rock. They are shown on Diagram 3. On these the high and low water levels are shown, but it must be kept in mind that the high water lasts but for so brief a period that it does not prevent trees from growing over nearly all the bottom-lands. The shortness of the time of high water not only prevents much erosion, but the presence of the trees greatly retards the flow of the water, and makes

its currents more gentle than in the ordinary river-channel. Where the bed-rock has been reached on all rivers in this country, it is overlaid by many bowlders, indicating the swift currents which moved such rocks along at the period of greater erosion. These bowlders sometimes form a stratum several feet deep, and often prevent boring-rods from reaching the bed-rock, but whenever they are thus found to be close together they indicate that the bed-rock is not far beneath.

No. 1 is at Big Stone Lake, about 3 miles above the outlet. The width of the lake is about 1 mile; the width between the bluffs is about 1½ miles. The depth of the water is about 6 feet; the rise from low to high water, 5 feet. The bluffs, banks, and bed of the lake are in the drift formation. The depth to bed-rock was not ascertained, but it is believed to be but a few feet below the present bed, as rock appears in the valley at the lower end of the lake. The rock is granitic. No rock *in situ* was found in the bluffs or ravines.

No. 2 is a section 150 miles below No. 1 and 1 mile below the mouth of the Blue Earth River. The river here at low water is 300 feet in width. The rise from low to high water is about 28 feet. The depth to rock is not known. At time of high water it reaches from bluff to bluff, a distance of 1½ miles. The lower 40 feet of the bluff is a soft sandstone capped by magnesian limestone about 40 feet thick, and this is covered by drift. This sandstone is called by D. D. Owen, Lower or Potsdam. It is very friable, and when exposed is rapidly eroded by atmospheric changes.

No. 3 is near the mouth of Minnesota River, 72 miles below No. 2. The valley here is about three-quarters of a mile wide between the bluffs. The high-water river extends from bluff to bluff. The low-water width of the river is 350 feet, the depth 12 feet, the rise from low to high water 22 feet. The depth to bed-rock is not definitely known, but is more than 60 feet. The bluffs for the first 80 feet are of soft friable sandstone capped by about 15 feet of hard magnesian limestone, and above this from one-quarter to one-half mile from the river with drift from 50 to 75 feet in height. The base of the bluffs on this section and in the lower part of the Minnesota Valley are protected from erosion by the limestone that has fallen into it, the sandstone being washed away from beneath it.

No. 4 is a section across the valley one-half mile below No. 3, and below the junction of the Mississippi and Minnesota. The low-water width of the river here is about 700 feet, and the high-water width from bluff to bluff about 1½ miles. The rise from low to high water is about 22 feet. The character of the rocks composing the bluffs and their height are the same as in section No. 3. The increased volume of water carries away the greater part of the soil at the foot of the bluffs, so as to leave but little except the *débris* of the limestone fallen from above.

No. 5 is a section of the valley of the Mississippi River immediately above its junction with the Minnesota River. The river occupies nearly the full width between the bluffs, which are less than 1,000 feet apart. The bluffs rise almost perpendicularly from the river, so that it is difficult to find an approach for a carriage-road. The character of the rock composing the bluffs is the same as that in sections 3 and 4 and at Falls of Saint Anthony. The sandstone in these three sections is called the Saint Peter's sandstone by Owen, or No. 3 of the ascending series of the Lower Silurian age, the Potsdam sandstone being No. 1. It is the same as the upper sandstone, or Saint Peter's sandstone, of Hall and Worthen.

No. 6 is a section of the Mississippi Valley at Hastings, Minn., 26 miles below section No. 4. The river here at low water is about 500

feet wide; at time of high water it extends from bluff to bluff, nearly 1 mile. The low-water depth of the river is about 16 feet. In driving piles for the railroad-bridge no rock was struck, so that the bed-rock is more than 40 feet below low water. The rock appears on the right bank at low water, and rises as you leave the river; 1 mile from the river it is about 130 feet high. In the opposite bluff no rock was seen, but it appears a short distance up river. The bluffs are steep, and are from 120 to 200 feet high. The rock composing the bluff is a magenesian limestone, too porous to make a good building-stone, but still a hard stone that withstands atmospheric changes well. The tops of the bluffs are covered with drift of varying depths.

No. 7 is 42 miles below section 6 and near the lower end of Lake Pepin. The width of the lake is about 2½ miles, and the width of the valley is about 3 miles. The low-water depth of the lake is about 60 feet. The rise from low to high water is 17 feet. The bluffs are about 400 feet high; the lower 200 feet is of Potsdam sandstone and the upper 200 of magnesian limestone. The base of the bluffs is protected by a talus of magnesian limestone, which has fallen from the bluffs above. The depth to bed-rock is not known.

No. 8 is a section of the valley near La Crosse, Wis., 62 miles below section No. 7. The low-water width of the river here is about 1,300 feet, the high-water width is about 4 miles. The rise from low to high water is about 16 feet. The valley from bluff to bluff is about 5 miles wide, about one mile being occupied by a sand terrace above overflow. The rock of which the bluffs are composed is a soft sandstone (Potsdam) for about 320 feet above low water, capped with 15 feet of magnesian limestone. The depth to the bed-rock in the valley is not known. In building the railroad bridge at this place, piles were driven to a depth of 60 feet below low water and no rock struck.

No. 9 is a section of the valley at Prairie-du-Chien, Wis., 56 miles below No. 8. The low-water river here is divided by an island into two channels with a total width of 1,800 feet. The rise from low to high water is about 22 feet. The width of the river at high water is about 1¼ miles. The whole width of the valley is about 2½ miles, 1¼ miles on the left or east side being occupied by a sand terrace, upon which the town of Prairie-du-Chien is built. The bluffs from the first 165 feet above low water are of magnesian limestone, the next 60 feet of a soft sandstone (upper or Saint Peter's), capped by 175 feet of magnesian limestone, covered with drift of varying depths. The depth to bed-rock is not known. It is probably in excess of 50 feet below low water, as it has not been struck in driving piles in the river, and some in the deepest water must have reached nearly to that depth.

No. 10 is a section of the valley at Dubuque, Iowa, 55 miles below No. 9. The low-water width of the river is about 1,700 feet, the high-water width of the river is about 1 mile, and extends from bluff to bluff. The rise from low to high water is about 20 feet. The depth of the low water is about 16 feet. The depth to bed-rock is not known, but it is greater than 4 feet below low water. The bluffs are of limestone, about 200 feet in height. This limestone is known as the Galena limestone. It is dolomite, being composed of nearly equal parts of lime and magnesia. It is a hard stone but not uniformly so; some parts eroding more rapidly than others give the bluffs a castellated appearance. In the crevices of this formation nearly all of the lead of this section has been found. The want of homogeneity prevents this stone being much used for building purposes. The base of the bluffs and the river banks are completely covered with the *débris* from the bluffs. The peculiar fea-

ture of this section—its narrowness—may be due to the resistance of the rock to erosion.

No. 11 is a section of the valley at Rock Island, Illinois, 88 miles below No. 10. The river is here divided into two channels by the island of Rock Island; the whole width of the river is 2,800 feet. The low and high water widths are nearly the same, the banks rising nearly perpendicularly. The rise from low to high water is 16 feet. The bed of the river, the island, and lower part of the bluffs are of limestone, somewhat hard and much fractured. The tops and sides of the bluffs are covered with drift and loess. The whole width between the bluffs is about 1½ miles. This section is across the valley near the lower end of Rock Island Rapids which extend from Le Claire, Iowa, to Rock Island, a distance of 14 miles. The bed of the river throughout this distance is of limestone of the same character as at this section. No. 12 is a section of the valley at Burlington, Iowa, 65 miles below No. 11. The low-water width of the river here is about 2,500 feet, the high-water width is from bluff to bluff, a distance of nearly 5 miles. The rise from low to high water is 20 feet. The depth to bed-rock is not known. Piles driven for the railroad bridge did not reach rock except for a short distance from the west shore. The bed-rock must therefore be more than 40 feet below low water, as piles in 10 feet water were driven 30 feet or more into the sand. The bluffs here are 100 to 150 feet high. The lower 30 feet of the bluff on the right bank is composed of sandstone and green shale, referred by Hall to the Chemung group of New York. It is soft and erodes rapidly when exposed. This is capped by 100 feet or more of Burlington limestone. In the opposite bluff no sandstone is seen, the Burlington limestone only being exposed. Its height is about 100 feet.

No. 13 is a section of the valley at Keokuk, Iowa, 40 miles below No. 12. The low-water width of the river is 2,600 feet. The high-water width is from bluff to bluff, 1¼ miles. The rise from low to high water is 22 feet. The bed of the river is of rock throughout. It is a cherty limestone, which resists erosion because the dip of the strata corresponds closely with the slope of the river. The bluffs are from 100 to 150 feet high. The bluff on the right bank is 150 feet high, the first 100 feet above the river being of limestone capped by 50 feet belonging to the coal measures overlaid by drift. The bluff on the left bank has the same limestone but no exposure of rock representing the coal measures. This section is near the foot of Des Moines Rapids, which extend up to Montrose, 11 miles above. The bed of the river throughout this distance is rock of the same character as at the section.

No. 14 is at Quincy, Ill., 32 miles below No. 13. The low-water width of the river is 3,000 feet. The high water width of the river is about 4½ miles. The rise from low to high water is 20 feet. The depth to bed-rock in that part of the valley occupied by the low-water river is from 40 to 50 feet below low water. The width of the valley from bluff to bluff is about 6½ miles. The bluff on the right bank is about 100 feet high, of mountain limestone, covered by drift of varying depths; that on the left bank has 100 feet of the same formation capped by 30 or 40 feet of drift. The depth of the bed-rock is taken from the report by Mr. T. C. Clarke, civil engineer, chief-engineer of the Quincy railroad bridge.

No. 15 is at Louisiana, Mo., 4 miles below No. 14. The low-water width of the river is about 3,200 feet. The high-water width is from bluff to bluff, or 5¼ miles. The rise from low to high water is 20 feet. The depth to bed-rock was furnished me by Mr. E. L. Corthell, chief-engineer of Suy Carte Levee Company. The greatest depth on this section below low water is about 80 feet. It is not improbable that this depth may be

from 10 to 20 feet short of bed-rock. The borings for this section were made with a seven-eighth-inch diameter rod, jointed in lengths of 10 feet, and forced down by manual labor, men turning and thrusting alternately by means of handles secured to the rod by set-screws. The lower end of the rod was armed with an auger point, making one turn or thereabouts. The bluff on the right bank is about 300 feet high. In this bluff we have rocks of the Upper and Lower Silurian, Devonian, and Sub-Carboniferous ages. In the opposite bluff the same, except the Lower Silurian. This upheaval or tilting up of the older rocks continues to Cap au Gris where the upper or Saint Peter's sandstone forms a bluff of more than 100 feet in height. Immediately below Cap au Gris is a "downthrow"; all of the older formations disappear and we have a bluff composed wholly of Sub-Carboniferous limestone.

No. 16 is at Saint Louis, Mo., 86 miles below No. 15. The low-water width of the river here is about 1,500 feet; the high-water width of the river is about 6 miles. The rise from low to high water is 41 feet. The greatest depth to the bed-rock, as determined in that part of the valley occupied by the low-water river, is 90 feet. The width of the valley between the main bluffs is about 7½ miles. On the right bank the rock appears at the river's edge at low water, and rises gradually to a height of 100 feet; above this the drift or loess is in varying thickness from 20 to 60 feet. The rock is a hard limestone. On the left bank limestone is found to about the same height, overlaid by drift or loess. The eastern part of the valley on this section is the great American bottom. Most of this is above the usual high water; extreme high waters, however, overflow the greater portion of it.

No. 17 is a section of the Mississippi Valley at Fountain Bluff, Ill., 88 miles below No. 16. The low-water width of the river is about 2,600 feet; the high-water width is about 3 miles. The rise from low to high water is about 44 feet. The bluffs are 200 to 300 feet high. The river, except at times of high water, flows between the main bluff on the right bank and Fountain Bluff. Fountain Bluff is an isolated bluff standing in the valley; it is about 4½ miles long and 1¾ miles wide in its widest part. The lower 50 feet of this is of limestone, capped by upwards of 200 feet of conglomerate of the coal measures. The bluff on the right bank is of the same formation, but not so high. The bed of the low-water river is rock. In that part of the valley between Fountain Bluff and the main bluff, east of the Big Muddy River, the depth to bed-rock is not known, but it is believed to be far greater than in that part occupied by the low-water river. The main bluff on left bank is of limestone Immediately below this section an "upheaval" brings rocks belonging to the Upper Silurian age to the surface. "Devil's Oven," "Grand Tower," and "Back Bone" are of these rocks.

No. 18 is at Commerce, Mo., 35 miles below No. 17. The low-water width of the river is about 700 feet; the high-water width is from bluff to bluff about 3,400 feet. The rise from low to high water is 48 feet. The bed of the river is of rock from bluff to bluff; rock rises above low water except in the low-water channel. These bluffs and the bed of the river is a limestone belonging to the Lower and Upper Silurian. This section is of special interest by reason of its narrowness. The distance between the bluffs is less here than at any place between Lac Traverse and the mouth of the Ohio. An opening in the bluffs on the right bank between Cape Girardeau and Gray's Point, some 5 miles above this section, leads through to the Whitewater River. This opening, some 3 miles in width, before the building of a levee across it,

carried off a portion of the flood-waters of the river. In 1844 it was overflowed to a depth of 12 feet.

No. 19 is a section of the Missouri Valley at Saint Charles, Mo., where the river debouches into the Mississippi Valley. The low-water width of the river is about 2,000 feet; the high-water width is about 2 miles; the rise from low to high water is 40 feet; the depth to bed-rock in the part shown is about 75 feet; the width of the valley from bluff to bluff is about 2¼ miles; the rock in the bluffs for 50 to 70 feet above low water is of limestone. This is capped by from 40 to 70 feet of drift loess.

This section of the Missouri was furnished by General C. Shaler Smith, civil engineer, chief engineer of the Saint Charles Railway bridge.

No. 20 is a section of the Illinois River Valley, about 5 miles above the mouth of the river. The high-water width of the river is about 2 miles; the river between low and high water is about 39 feet; the width of the valley between the bluffs is about 2¼ miles; the bluffs are about 150 feet high and of limestone.

Contour map of the sources of the Mississippi.—We have prepared a small contour map of this region, using all the available determinations of elevations above the sea. It would take considerable space to acknowledge the sources individually; the large collection of this data made by Mr. Gannett, member of the Geological Survey of the Territories, has been particularly useful. But the drawing of the lines has been mainly the result of our own knowledge of the region. Contour lines are given for each 200 feet from 600 feet up to 2,000 above the sea-level. The object of making this map is to show the important position in this system of contours occupied by the Minnesota River.

We have also prepared a table giving the area drained by each tributary of the great valley down to and including the Ohio. This will be found useful for many purposes. As a matter of interest to the curious, it may be noted that if the area of the present Lake Winnipeg basin be added to that of the Mississippi, above the junction of the Missouri, it will about equal the area of the basin drained by the Missouri.

Warren's Rep't Bridging Miss. R. *Diagram G*

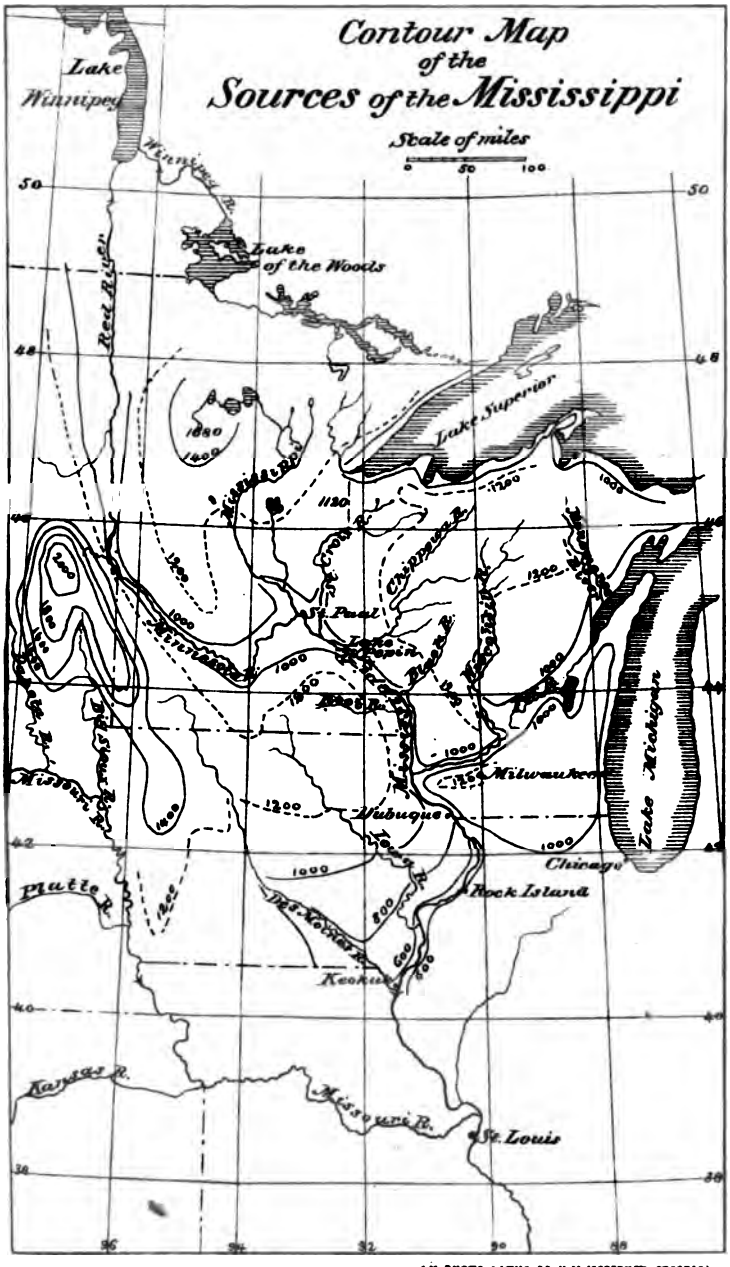

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Table of areas of basins drained by the tributaries to the valley.

Name.	Miles drained.	Total miles drained.	Distance apart.	Total distance.	Right bank.	Left bank.
ta River	310	310	.....	.....	R. B.	.....
ne or Izuza River	110	420	30	30	R. B.	.....
Banks River	340	760	6	36	R. B.	.....
de Terre River	960	1,720	13	49	.....	L. B.
parle River	830	2,550	15	64	R. B.	.....
/a River	1,970	4,520	10	74	.....	L. B.
Medicine River	650	5,170	20	94	R. B.	.....
)a or Hawk Creek	470	5,640	1	95	.....	L. B.
l River	770	6,410	20	115	R. B.	.....
Creek	240	6,650	2	117	.....	L. B.
onwood River	980	7,630	37	154	R. B.	.....
ttonwood River	245	7,875	4	158	R. B.	.....
rth River	3,350	11,225	16	174	R. B.	.....
Creek	57	11,282	15	189	R. B.	.....
e Sueur River	144	11,426	7	196	R. B.	.....
ver	102	11,528	2	198	.....	L. B.
land Creek	75	11,603	6	204	.....	L. B.
eek	234	11,837	18	222	R. B.	.....
Creek	100	11,937	1	223	.....	L. B.
tiver	140	12,077	15	238	R. B.	.....
le Creek	42	*12,119	2	240	.....	L. B.
ppi River	21,600	33,719	9	249	.....	L. B.
olx River and Lake	7,568	41,287	30	279	.....	L. B.
lon River	237	41,524	3	282	R. B.	.....
le River	95	41,619	9	291	.....	L. B.
River	1,639	43,258	5	296	R. B.	.....
River	73	43,331	5	301	.....	L. B.
iver	183	43,514	4	305	.....	L. B.
ra River	9,602	53,116	18	323	.....	L. B.
ver	452	53,568	9	332	.....	L. B.
River	1,366	54,934	9	341	R. B.	.....
ater River	382	55,316	1	342	R. B.	.....
reek	158	55,474	9	351	.....	L. B.
Stone Creek	136	55,610	6	357	R. B.	.....
leau River	700	56,310	10	367	.....	L. B.
iver	2,880	59,190	18	385	.....	L. B.
se River	463	59,653	.....	385	.....	L. B.
ver	1,685	61,338	4	389	R. B.	.....
Creek	139	61,477	7	396	.....	L. B.
Creek	70	61,547	3	399	R. B.	.....
River	180	61,727	7	406	.....	L. B.
owa River	939	62,666	3	409	R. B.	.....
reek	70	62,736	25	434	R. B.	.....
River	279	63,015	4	438	R. B.	.....
sin River	11,850	74,865	7	445	.....	L. B.
River	1,679	76,544	21	466	R. B.	.....
iver	289	76,833	13	479	.....	L. B.
tiver	306	77,139	6	485	.....	L. B.
lakoqueta	150	77,289	3	488	R. B.	.....
Creek	75	77,364	7	495	R. B.	.....
omonee Creek	32	77,396	4	499	.....	L. B.
ra Creek	50	77,446	4	503	.....	L. B.
Mort Creek	45	77,491	1	504	R. B.	.....
iver	185	77,676	3	507	.....	L. B.
ek	35	77,711	7	514	R. B.	.....
eta River	1,863	79,514	7	521	R. B.	.....
tiver	245	79,819	4	525	.....	L. B.
reek	85	79,904	2	527	.....	L. B.
iver	280	80,184	6	533	.....	L. B.
inican River	2,490	82,674	28	561	R. B.	.....
ver	10,690	93,364	25	586	.....	L. B.
s Creek	25	93,389	26	612	.....	L. B.
ver	12,250	105,639	15	627	R. B.	.....
's River	43	105,682	2	629	.....	L. B.
eek	135	105,817	4	633	.....	L. B.
on River	625	106,442	18	651	.....	L. B.
reek	165	106,607	4	655	R. B.	.....
s Creek	104	106,711	3	658	.....	L. B.
Creek	65	106,776	5	663	.....	L. B.
River	4,322	111,098	1	664	R. B.	.....
reek	150	111,248	18	682	R. B.	.....
nes River	14,955	126,203	32	714	R. B.	.....
er	479	126,682	4	718	R. B.	.....
eek	418	127,100	15	733	.....	L. B.
da Creek	480	127,580	5	738	R. B.	.....

*Total of Minnesota Rivers.

Table of areas of basins drained by the tributaries to the valley.

Name.	Miles drained.	Total miles drained.	Distance apart.	Total distance.	Right bank.	Left bank.
Fabius River	1,590	129,170	13	751	R. B.	.....
North River	465	129,635	2	753	R. B.	.....
Mill Creek	96	129,731	3	756	.....	L. B.
McDonald's Creek	140	129,871	13	769	.....	L. B.
Salt River	2,741	132,612	18	787	R. B.	.....
Noix Creek	52	132,664	3	790	R. B.	.....
Buffalo Creek	40	132,704	1	791	R. B.	.....
Bobb's Creek	90	132,794	13	804	R. B.	.....
Gwinn's Creek	25	132,819	2	806	R. B.	.....
Bryant's Creek	75	132,894	19	825	R. B.	.....
Cuivre Creek	1,180	134,074	9	834	R. B.	.....
Peragne Creek	90	134,164	3	837	R. B.	.....
Dardenne Creek	110	134,274	6	843	R. B.	.....
Illinois River	27,465	161,739	8	851	.....	L. B.
Big Pisa Creek	100	161,839	10	861	.....	L. B.
Missouri River	518,000	679,839	10	871	R. B.	.....
Wood River	145	679,984	.....	871	.....	L. B.
Cahokia Creek	400	680,384	17	888	.....	L. B.
Meramec River	3,715	684,099	18	906	R. B.	.....
Eagle Creek	70	684,169	7	913	.....	L. B.
Platin Creek	110	684,279	5	918	R. B.	.....
Lisle de Bois Creek	50	684,329	9	927	R. B.	.....
Establishment River	110	684,439	6	933	R. B.	.....
Rivière aux Vases	100	684,539	4	937	R. B.	.....
Saline River	240	684,779	12	949	R. B.	.....
Kaskaskia River	5,660	690,439	7	956	.....	L. B.
Saint Mary's River	215	690,654	4	960	.....	L. B.
Brazos Creek	40	690,694	24	984	R. B.	.....
Big Muddy River	2,245	692,939	6	990	.....	L. B.
Apple Creek	200	693,139	1	991	R. B.	.....
Clear Creek	135	693,274	18	1,009	.....	L. B.
Ohio River	.....	.....	42	1,051	.....	.....

NOTE.—When I made my first published statement, in 1868, that the drainage of the Winnipeg basin had formerly been southward along the Mississippi, I regarded it in a great measure as a discovery made by myself, and still think so. Recently I have found in the fine publication on "The Principal Diseases of the Valley of North America," by Daniel Drake, M. D., published in 1850, on p. 20, vol. 1, the following:

"A wide and deep current from the north must have excavated this trough across the continent, and Lake Traverse and Big Stone Lake are but hollows or chasms left filled with water when the river ceased to flow. They are long, narrow, serpentine, and lie in the course of the obsolete water. They resemble the pools of a wet-weather stream during a drought, or, more exactly, the crescent lakes of the Lower Mississippi, which, as we shall hereafter see, were once portions of its ancient channels."

The statement that Lakes Traverse and Big Stone resemble "more exactly the crescent lakes of the Lower Mississippi," shows that the character and significance of the lakes were not understood by the writer. They are not lakes left by bends of the river which made what is called a cut-off. They are straight, not serpentine. They occupy all the low valley, not a part of it, as cut-off lakes do. Such general remarks on the subject are found in many writers, but they are vague or incorrect, so that they possess no pointed significance, and are read without making any distinct impression upon the mind.

CHAPTER III.

GENERAL PRESENTATION OF REQUIREMENTS AND ADVANTAGES OF WESTERN RIVER NAVIGATION.—NECESSITY FOR WIDE, CLEAR SPANS AND HIGH BRIDGES; AND A DISCUSSION OF THE DATA ON UPPER MISSISSIPPI FOR DETERMINING HEADWAY UNDER BRIDGES.

Preliminary remarks—How steamboats are constructed—Necessity for high pilot-houses—Height of chimneys—Table of dimensions of steamboats—Barge transportation—Rafting—General remarks—Knowledge of varying stages important—Gauge data used—Gauge observations at Saint Louis and Rock Island compared for a period of sixteen years—Gauge observations at Saint Louis, Quincy, and Rock Island compared for a period of eight years. HEADWAY UNDER BRIDGES: 1st. Saint Louis tables, &c.—2d. Rock Island tables, &c.; comparison of conditions at Saint Louis and Rock Island with regard to headway—3d. Quincy tables, &c.; comparison of conditions at Saint Louis and Quincy with regard to headway—4th. Dubuque tables, &c.; comparison of conditions at Saint Louis and Dubuque with regard to headway—5th. Other places on the Mississippi where gauge observations have been made—General rule for equating headway at places having different ranges from high to low water—Table of ranges from low to high water on the Mississippi, Ohio, and Missouri Rivers.

Preliminary remarks.—When the bridging of the Ohio River at Wheeling was completed in 1849, the bridge was to meet the wants of a public highway (the "National Road"). The railroad system of the United States was then in its infancy, and the canal systems of the country were approaching their highest development. Compared with land or canal transportation west of the Alleghany Mountains, that of the steamboats was speedy, commodious, and luxurious.

The shallowness and other peculiarities of the Western rivers had developed a class of steamboats unlike anything to be found elsewhere, and admirably adapted to the conditions in which they were employed, and which, to a great extent, still exist, and will continue to exist, although in a large part of the Mississippi Basin (where rapidity of transit from place to place is required) they are now of less importance than railroads.

How steamboats are constructed.—As essential to the full benefits of this navigation, the hull of the vessel must be lightly timbered, broad, flat-bottomed, and but a few feet in depth. This shape is rendered necessary by the shoalness of the river at ordinary low-water stages. In practice the deck rises but a little above the water, varying from a few inches to ten feet.

The boilers are high pressure, of horizontal tubular form, with flues, and are placed side and side on the main-deck. The boiler-deck next above is laid at as low height as will give proper free space above the boiler and also allow room for storing fuel and the bulky freight which forms much of their cargo.

The means of supplying fuel has been an important factor in the construction of the Western-river steamboats. Cord-wood suitable for their use was at first everywhere to be procured along the banks. Its bulk required considerable room for storage, conveniently located with reference to the boilers, to be readily used, and also to be easily taken on board from the banks or from scows alongside.

Coal is rapidly taking the place of wood, but it requires nearly the same arrangements; for although taking up less room, its weight requires it to be frequently renewed, and most of the boats run upon rivers, or are liable to, where wood must be used. Therefore grate-bars are generally adapted to the use of both wood and coal. Where the coal is sulphureous, coal and wood are used together.

The cabin for passengers, covered by the hurricane-deck, comes next above the boiler-deck, and is of sufficient height for comfort and ventilation. Above the hurricane-deck is another cabin called "the texas," allotted to the crew. Upon the texas the pilot-house is placed.

Necessity for high pilot houses.—The elevated position of the pilot-house is of very great importance, and the reasons for it will be given. The channels of best water are all the time changing, and differ in position one season with another, so that the pilot has to find the best water by means of the indications on its surface made by underlying shoals or obstructions. This can only be done in daylight, and in order to run at night, the pilot must take landmarks in the day-time to be his guide after dark.

A great amount of ready knowledge is thus necessary to pilots on regular lines of steamboats which run at night. In this elevated position the pilot is enabled to see well around his boat, astern as well as forward; has a better view of the signs of deep and shoal water when the water surface is not obscured by mists; commands a better view of the shores and objects upon it which are his marks in the night; and is often for some hours unable to see over the mists rising from the water after the view from the main deck and lower parts of the vessel has been lost. Many hours of navigation are thus saved and delays prevented which would seriously injure business.

Every thing depends upon the pilot, and his knowledge and skill, so that the elevated position of the pilot-house is essential. But not only this, the whole arrangement of the boat is designed to facilitate the pilot's command over her movements.

All the side-wheel boats have separate engines for each paddle-wheel, to be used singly as the pilot may direct, and bells are arranged for him to signal to the engineers, generally too complicated to admit of any lowering of the pilot-house to pass under a bridge, without liability of destroying the certainty of their indications, any misinterpretation of which might destroy the vessel at once.

The side wheels are placed far aft, to facilitate the handling of the boat, and very wide rudders are employed. Stern-wheel boats are much less manageable than the others, except in towing, and there, by means of ropes from the tug to the "tow," compensation is made for having but one paddle-wheel.

The boats running on the Ohio to Pittsburgh in 1849 had pilot-houses about 48 feet above the water, and the length of the boats was about 230 feet. In order to afford proportionally commanding view to the pilot on boats of greater length, the pilot-houses would have to be increased in the same ratio, so that one of 300 feet length would require a height of about 60 feet. This is about the actual conditions of existing practice.

The Thompson Dean, a Saint Louis and New Orleans packet, being 306 feet long, top of pilot-house 67 feet above water; some few feet of this in excess of this ratio (made for ornament) might be dispensed with without practical injury.

Height of chimneys.—In all the practice, until very recently, the reliance for draught in the furnaces has been the effect produced by high and large chimneys. It was shown in the suit against the Wheeling bridge that the chimneys could not be shortened without loss of power and speed, and that attempts to employ shorter pipes and blowers has been made and failed.

Where the navigation has never been obstructed by bridges interfering with the height of chimneys, this practice, founded on experience, has not

been departed from. Besides giving draught, the sparks coming out at such great height fall overboard or are cooled, so as to not engender fires when falling on the decks, as they would with low chimneys Chimneys of boats on the Ohio in 1849 were near 80 feet above water in some cases; their diameter was not less than 5 feet, and their weight near two tons each.

The height of chimneys increased as the boats were built larger, till on the James Howard, in 1874, the chimneys were 104 feet above the water, and those of the Great Republic were said to be higher.

The navigation interests on the Upper Mississippi seem willing now to concede that if the bridge is high enough to allow the pilot-houses to pass under it at high water, the experience they have had in shortening their pipes and adding blowers will enable them to make pipes that shall extend only 8 or 10 feet above the pilot-house of such size as to be easily lowered. The pipes must be at least this high above the pilot-house to prevent the pilot being interfered with by the smoke.

Tables of dimensions of steamboats.—The following tables, giving the heights of different parts of different vessels, are taken from the report of the Board of Engineers on the bridges of the Ohio River and the report of the Board of Engineers on the Saint Louis bridge. The former is contained in Annual Report Chief of Engineers for 1871, page 448, the latter in Annual Report Chief of Engineers for 1874, vol. 1, pp. 648, 649:

Names and dimensions of some of the largest boats employed on the Ohio River above Cincinnati.

Names of boats.	Top of pilot-house above water.	Top of texas above water.	Top of cabin above water.	Top of chimneys above water.	Length of boat.	Width over all.
	Ft. in.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Fleetwood	48 0	34 0	29 0	75 0	260 0	70 0
Telegraph	47 3	34 3	29 0	77 0	251 0	68 0
Saint Charles	47 0	34 6	26 2	68 0	273 0	70 0

Names and dimensions of some of the largest boats employed on the Mississippi River, and which pass the city of Saint Louis, Mo.

PASSENGER-PACKETS.

Names of boats.	Top of pilot-house above water.	Top of texas above water.	Top of cabin above water.	Top of chimneys above water.	Length of boat.	Width over all.
	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
James Howard	69 0	.....	.....	104 0	.....	.....
Thompson Dean	67 0	46 4	36 8	91 4	306 0	79 4
Phil. Sheridan	65 8	36 2	27 8	72 8	222 0	62 0
I. H. Johnston	65 8	36 2	27 8	72 8	246 0	62 0
Andy Johnson	63 2	36 2	27 8	80 8	273 0	72 0
Jo Kinney	62 3	35 9	27 9	75 9	241 6	65 0
Tom Jasper	62 0	37 6	27 10	72 0	257 0	63 0
Richmond	61 2	45 0	35 5	97 5	340 0	80 0
John A. Scudder	59 7	43 10	34 2	94 2	306 0	88 0
Dexter	59 0	44 0	33 10	87 10	340 0	89 0
Grand Tower	58 4	41 0	32 0	90 0	276 0	73 0
Lucy Bertram	58 4	34 4	26 2	76 2	250 0	67 0
Continental	57 0	40 6	31 4	83 4	288 0	73 0
City of Helena	56 10	40 4	31 4	93 4	277 0	74 0
Pauline Carroll	56 8	42 0	32 0	88 0	266 6	77 0
Belle of Memphis	56 0	40 0	31 0	93 0	273 0	72 0
Exporter	55 0	39 0	32 0	77 0	238 0	62 0
City of Chester	55 0	38 10	30 0	84 0	250 0	70 0
Henry Ames	54 10	39 9	31 0	83 0	305 0	74 0
Julia	54 8	34 8	27 4	83 4	243 6	70 0
Emma C. Elliott	53 8	38 0	28 3	82 3	222 0	63 6
Commonwealth	53 0	39 0	30 0	84 0	264 0	73 8
Illinois	52 9	35 3	27 8	67 8	210 0	50 0
Susie Silver	52 4	37 2	28 0	86 0	265 0	68 0
John Kyle	52 1	38 3	31 1	83 1	299 0	78 6
P. W. Strader	51 8	35 8	26 8	80 8	233 0	56 6
City of Quincy	50 10	36 10	29 6	79 6	280 0	76 0
Rob Roy	50 4	36 0	27 4	79 4	273 0	73 0
Lake Superior	49 9	35 0	27 8	76 8	245 0	64 0
Clinton	49 9	35 11	27 8	73 8	253 0	65 0
Northwestern	46 7	29 11	21 7	65 7	257 0	72 0
Fanny Keener	46 5	33 11	25 7	67 7	208 0	40 0

Great Republic, not in port, higher than that of any on this list, and runs to sugar refinery and elevator, above the bridge.

TOW-BOATS.

Names of boats.	Height of pilot-house above water.	Height of chimneys above water.	Length over all.	Width over all.
	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Mohawk	64 3	78 3	189 0	35 0
Future City	51 0	75 5	222 0	46 4
Saint John	37 8	59 0	200 0	44 0
Atlantic	37 8	64 8	191 0	33 5

Crescent City, Mary Alice, and Bee, not in port, are as high as, and two of them are higher than, those given in the above list.

Among the above-named boats the Phil. Sheridan has run as a regular packet between Saint Louis and Saint Paul, but those best adapted to the trade are of the size of the Lake Superior.

The foregoing is intended only as a general presentation of the question of steamboat navigation with reference to bridges on Western rivers. I would specially call attention to the reports of the two boards of engineers just quoted from, as giving much more complete presentation of the subject in the special cases treated.

Barge transportation.—At the time the Wheeling bridge was built, in 1849, the system of transportation of coal down stream from Pittsburgh by means of large assemblages of flats and barges, pushed and guided by tug-boats, had not come into use. A draw space of 200 feet between the piers was considered sufficient provision for all requirements, and some thought that 100 feet was ample.

The barge system had, however, come into important use by the time the Steubenville Bridge Company made efforts to obtain legislation in Congress authorizing a bridge across the Ohio River. A width not less than 300 feet in the clear was established by the law, but the coal navigation interests strove to secure not less than 500 feet. This width is only needed by the heavily-loaded descending tows. Only the empty barges are taken back up stream, and less width is required for them. Subsequent laws of Congress require spans of not less than 400 feet in the clear on the Ohio below the mouth of the Big Sandy River, and one bridge is just finished in a bend at Cincinnati giving a clear span of 500 feet.

The necessity for wide spaces for barge navigation is very great on Western rivers. In the first place, the navigable depth of water is so little, that the surface of the submerged parts of the hull of the tug have but little hold upon the water compared to the large surface exposed to the wind, and is, therefore, more affected by the winds than vessels navigating deep water. The tugs and barges have flat bottoms and no keels, and slide easily sidewise. At shoal places the vessels barely float over the sand-bars, and this proximity also seriously affects the steering of the boat.

On account of shoals and winds, and sometimes on account of eddies and oblique currents, the vessel or tow can only be kept on the proper course by being held somewhat obliquely to it, thus occupying space more than the mere width. In towing, the object is placed well in front of the tow-boat and rarely alongside, and where there is an odd number of barges towed, or other inequality which prevents equal parts being placed on each bow, this inequality is regulated by varying the obliquity.

In considering the passage of vessels with tows between piers or around bends of the channels, this arrangement must always be kept in view.

The barges are arranged three, four, five, or more abreast, and as many in number behind each other, firmly lashed together. Behind these the tug is placed, suitably attached. The sizes of these tows depends only upon the width and depths of the river channels where bridges do not interfere. Bridge openings should therefore be proportioned to the size of the river. As extreme cases, we have on the Lower Ohio and Mississippi coal-tows of as high a number as 32 barges, conveying 539,000 bushels of coal, and it is proposed to make up large grain barges into fleets at Saint Louis, carrying 100,000 bushels of grain and more. On the Upper Ohio the coal fleets are made smaller, the size depending upon the stage of the river. On the Upper Mississippi very large fleets of light-draught barges are practicable if it were not for the draw-bridges, as is shown by the large size of the rafts. It is not saying too much that the inland system of transportation practicable on the Mississippi and its tributaries furnishes a means of moving great

quantities of coal, ores, grain, &c., unequaled in the world. The transportation by means of barges will undoubtedly increase, and no restriction to its development to the fullest extent should be allowed by bridges or anything else.

Rafting.—The raft interest, which is of the utmost importance to the country in supplying cheap lumber, is now carried on by steamboats in the same manner as the coal-fleet system, and with much greater economy than formerly, when manual force at long oars was relied upon to guide these cumbrous floating masses.

This business, too, requires wide spans, much greater than those provided by existing draw-bridges, and high enough to allow the steamboats to pass under and guide the raft through. Large Upper Mississippi rafts are about 270 feet wide and 450 feet long, and all such have now to be made so as to separate in two parts to pass the draw-bridges on the Upper Mississippi. (See, further, report of Board of Engineers on sheer-booms; Annual Report Chief of Engineers for 1877, p. 817; also appendix to this report, contained in House Ex. Doc. No. 41, Forty-fourth Congress, second session.)

General remarks.—When the bridges across the Mississippi were authorized in 1866, the barge system of transportation had already made itself important there, and although the rafting by steam was not then practiced, the inapplicability of draw-bridges was seriously felt.

Railroads running in the direction of the river, however, were not yet developed, and passenger and mail transportation along it was of such great importance, that some persons much interested in the navigation thought that draw-bridges with 150 feet clear openings were superior to high bridges which gave headway of only 50 feet at high water.

The building of railroads has diminished the proportionate amount of passenger travel on the river, and increased the amount of bulky and heavy products and manufactures, and has already changed these relations.

The building of the bridge at Saint Louis, giving a headway of only 50 feet at ordinary extreme high water, has compelled a change in the boats running above, so that they are now prepared to pass under any bridge without trouble or delay which gives the same clear height and has spans of 300 to 400 feet width in the clear for rafts and barges, so that one permanent high bridge without draw fixes a limit of height for all places above, and when a boat is built to pass under one she can without more trouble pass all such. On the contrary, each draw-bridge causes its own obstruction, and the total obstruction increases with the number, which is now so great and liable to cause such detention as to prevent all regularity in running a line of steamboats.

Experience on the Upper Mississippi has shown that the proper site for a bridge is where the channel is straight and next to the bank of both high and low water. The channel spans, whether low draws or high fixed ones, would then be next the bank, which at all times would furnish the best guide for the pilot; and then the further reason that the side next the shore can be protected by piling or other means that will allow the vessels to rub against it with safety; and this location also permits of auxiliary works being built out from the opposite shore to make the channel permanent.

Such locations cannot readily be made where the rise of the river from low to high water much exceeds 20 feet, because the necessary slope of the banks will require an open span between the margin of the low and high water shores. It is therefore not generally applicable to the Ohio, or Missouri, or to the Mississippi, below the mouth of the Illinois River.

On none of the Western rivers has nature prepared such a channel of navigation as upon the Mississippi above the junction of the Missouri. Its gentle slope and current, clear water, freedom from snags, limited range of height of floods, all render its navigation easy; and its condition is expressed to the eye of the traveler in its aspect of beauty. Its very gentleness has led to its being bridged with very trifling structures, which a turbulent stream like the Missouri would not suffer to stand. The latter has exacted much better bridge constructions on the average than those existing on the Upper Mississippi.

The navigation of the Upper Mississippi has a much more extensive interest than that represented by Saint Louis and the Upper Mississippi, considered by themselves. This navigation is but a part of a system which includes the whole Mississippi basin, the Ohio, the Missouri, the Illinois, &c. The vessels which navigate the Ohio should be allowed to carry their loads to Saint Paul as well as Saint Louis, and any structure which compels a change of character of vessel on the upper and lower sides of it, or a breaking of bulk, is simply an obstruction to navigation of the character of the rapids at Louisville, at Keokuk, and at Rock Island, which the government is spending large sums to remove.

In view of the probability that there will be before long a necessity for rebuilding some of the present draw-bridges at least, and substituting high ones, I have thought it proper to present the gauge data I have been enabled to get affecting the question of height of bridge when draw-spans are omitted, and discuss the question of headway under bridges. This has never been done, or even practicable until recently, for want of observations. This subject will form the remainder of this chapter.

Knowledge of varying stages important.—The surface of the water of the Mississippi is generally rising or falling, with occasional periods when it is stationary, and a knowledge of the annual average duration of these various stages is one of the important factors in considering the effect upon navigation of bridges of different heights at different places.

Gauge data used.—With the view to gain this knowledge we have obtained the most important *continuous* gauge-readings along the river, from the earliest records, which were made during the period between 1860 and 1876.

This period does not include any very remarkable floods, such as those of 1828, 1851, and 1858; but in some places it does the remarkable low waters which occurred in 1863 and 1864.

In the following presentation and discussion, records of gauge-readings have been obtained and used in comparison—

At Saint Louis, from January 1, 1861, to December 31, 1876.
At Quincy, from January 1, 1869, to December 31, 1876.
At Rock Island, from January 1, 1861, to December 31, 1876.
At Clinton, from October 17, 1866 and 1867, while river was open.
At Dubuque, from May 1, 1869, to December 31, 1876.
At Prairie du Chien during 1867, '68, '69, while river was open.
At Winona, from October 4, 1866, part of 1867, and 1868.
At Saint Paul during 1867, '68, '69, while river was open.

The observations at Saint Louis are kept at the expense of that city, part of which were furnished us direct, part were derived from the report of the board of engineers on the Saint Louis bridge, and part through the assistance of Maj. C. J. Allen, United States Engineers, in General Simpson's office. Those at Quincy were obtained from Chicago, Burlington and Quincy Railroad Company, through Mr. W. Beckwith,

superintendent of bridges. Those at Rock Island are from observations by the old bridge company up to 1869, and since then from observations made under direction of the engineer officers of the Army. Those at Dubuque were furnished by the bridge company, Hon. William B. Allison, president, through Mr. C. H. Booth, secretary.

All the foregoing named were obtained without expense to the survey. The others were made for the purposes of this investigation and at its expense.

The gauge-readings made at Keokuk might have been obtained, but its situation at the foot of the rapids destroys their general value, and the canal makes a bridge at this place a special one in character, to be determined by the necessities of the canal navigation.

There were other gauge observations attainable besides those named, but were not useful in the general consideration of this subject.

Gauge observations at Saint Louis and Rock Island compared for period of 16 years.—The longer period of continued observations at Saint Louis and at Rock Island makes the averages deduced from them more reliable than at any other points, although the situation of both these places is peculiar.

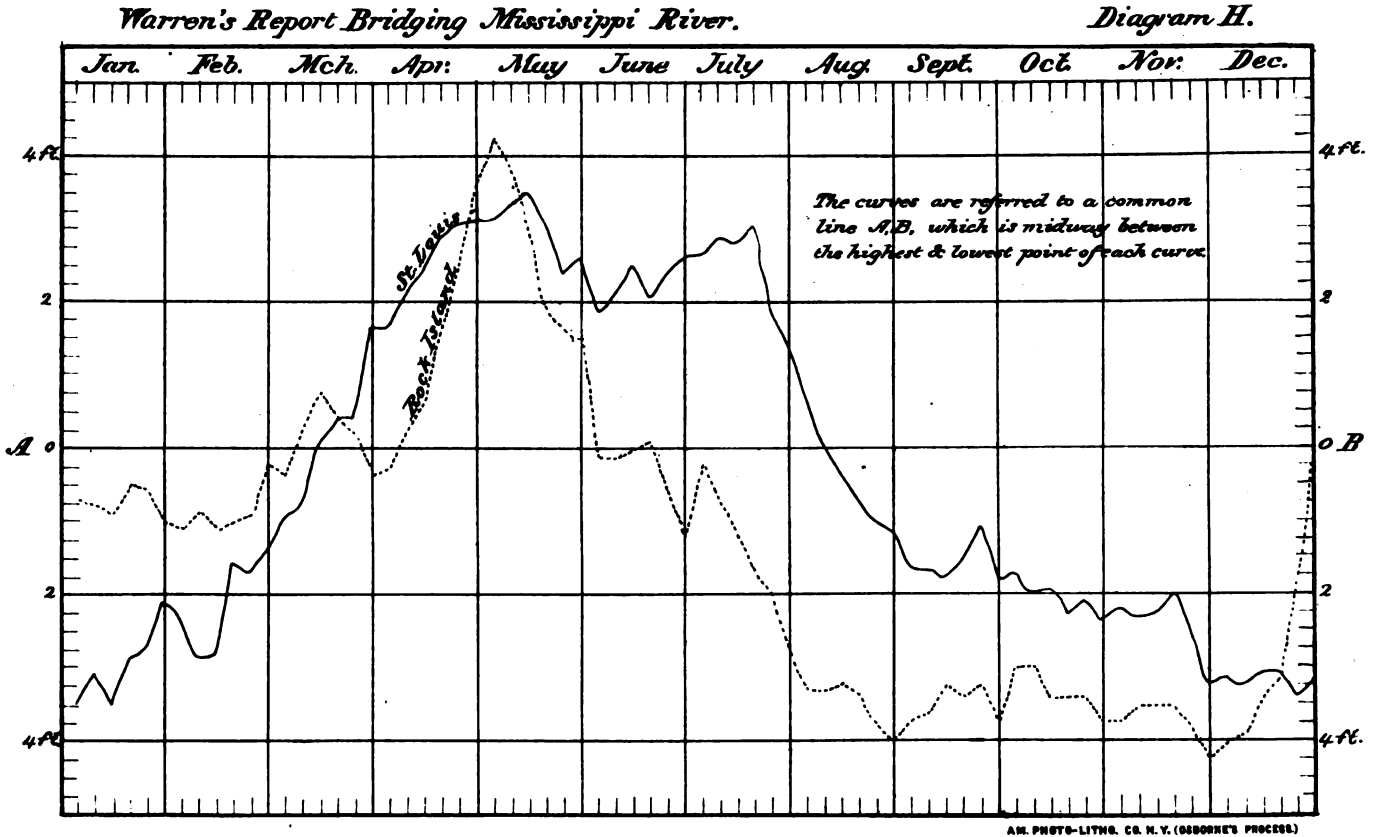
At Saint Louis the Mississippi is immediately affected by its long tributary, the Missouri River, and at Rock Island by the rapids. These peculiarities are shown in Diagram H, in which the average readings of the gauges are taken for the period, 16 years, between January 1, 1861, and December 31, 1876.

The gauge-readings at Saint Louis are divided by 2, so as to bring the two curves nearer together on the diagram. This does not give an equality of rise and fall, and therefore they are placed with the midway point in common, so as to divide the excess about equally at the times of high water in April and May, and that of the low waters in November and December. We might have made an exact equality of rise and fall by reduction, but this is near enough for this comparison. The peculiar differences show for themselves on the diagram. For instance, at Rock Island there is a rise in December, January, and February, not so marked at Saint Louis, which is probably due to the ice at Rock Island. With the spring rains there is a considerable uniformity of rise at the two places, but it reaches a greater relative height at Rock Island, and much sooner subsides.

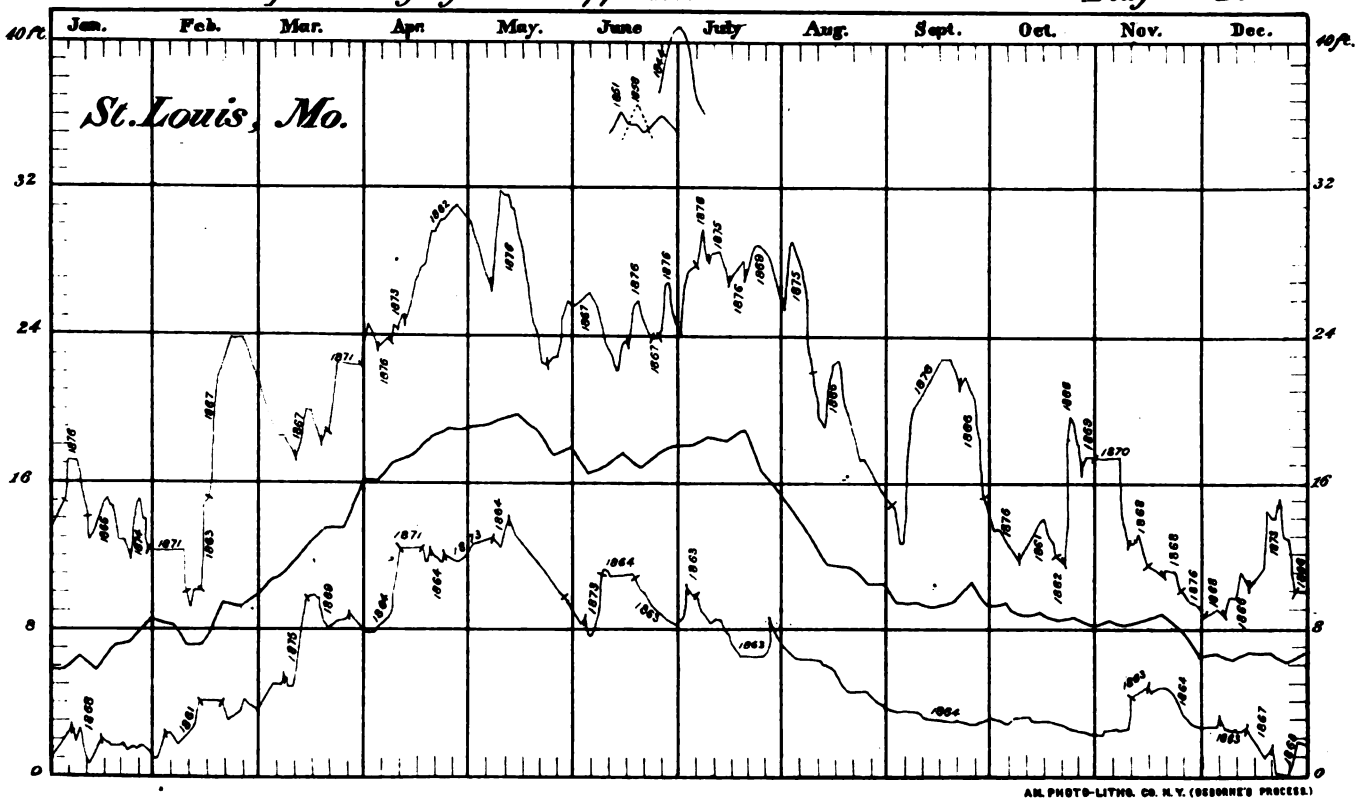
As a matter of further interest, we have prepared Diagram I for this 16-year period for Saint Louis, and Diagram J for Rock Island, giving the mean curve and the year when the highest and lowest water occurred on any day of the year. These show the extreme ranges that have been observed at the same dates in these 16 years, and the included space forms what we have called a *zone* of river oscillations, which includes all our known observations. The three exceptional high waters of 1844, '51, '58, recorded at Saint Louis, are noted on the diagram, but not included in the *zone*. We could not give each year's curve without too great confusion or resorting to colors which photolithography would not reproduce. These diagrams furnish interesting data for comparison and study, and information as to probability of high and low water at any time of the year, useful in planning engineering operations.

The daily observations are preserved in permanent records and can easily be procured when desired for any special purpose.

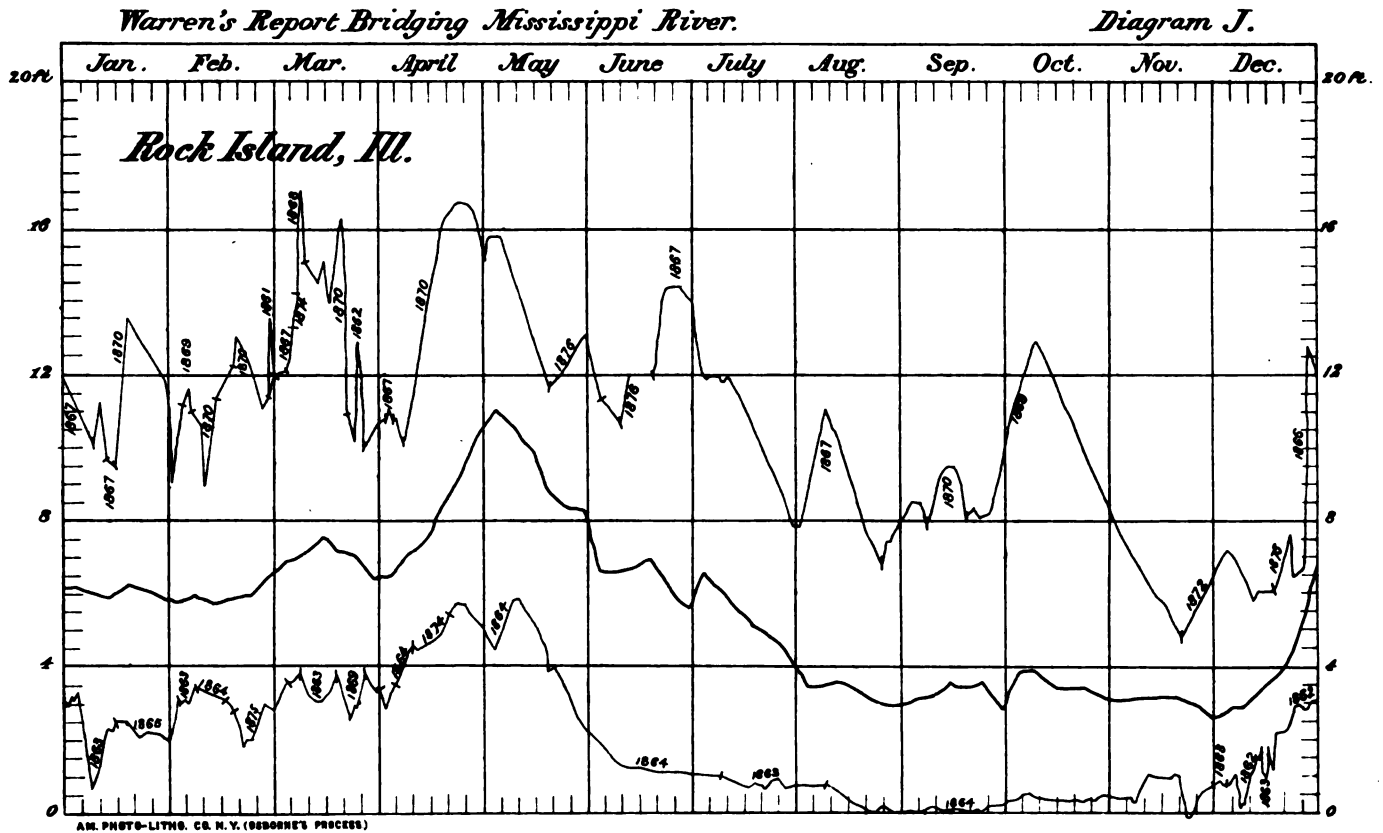
Comparison of means of gauge-readings at Saint Louis, Quincy, Rock Island, and Dubuque.—In order to see the effect of the natural conditions at Saint Louis and Rock Island, we have compared the simultaneous

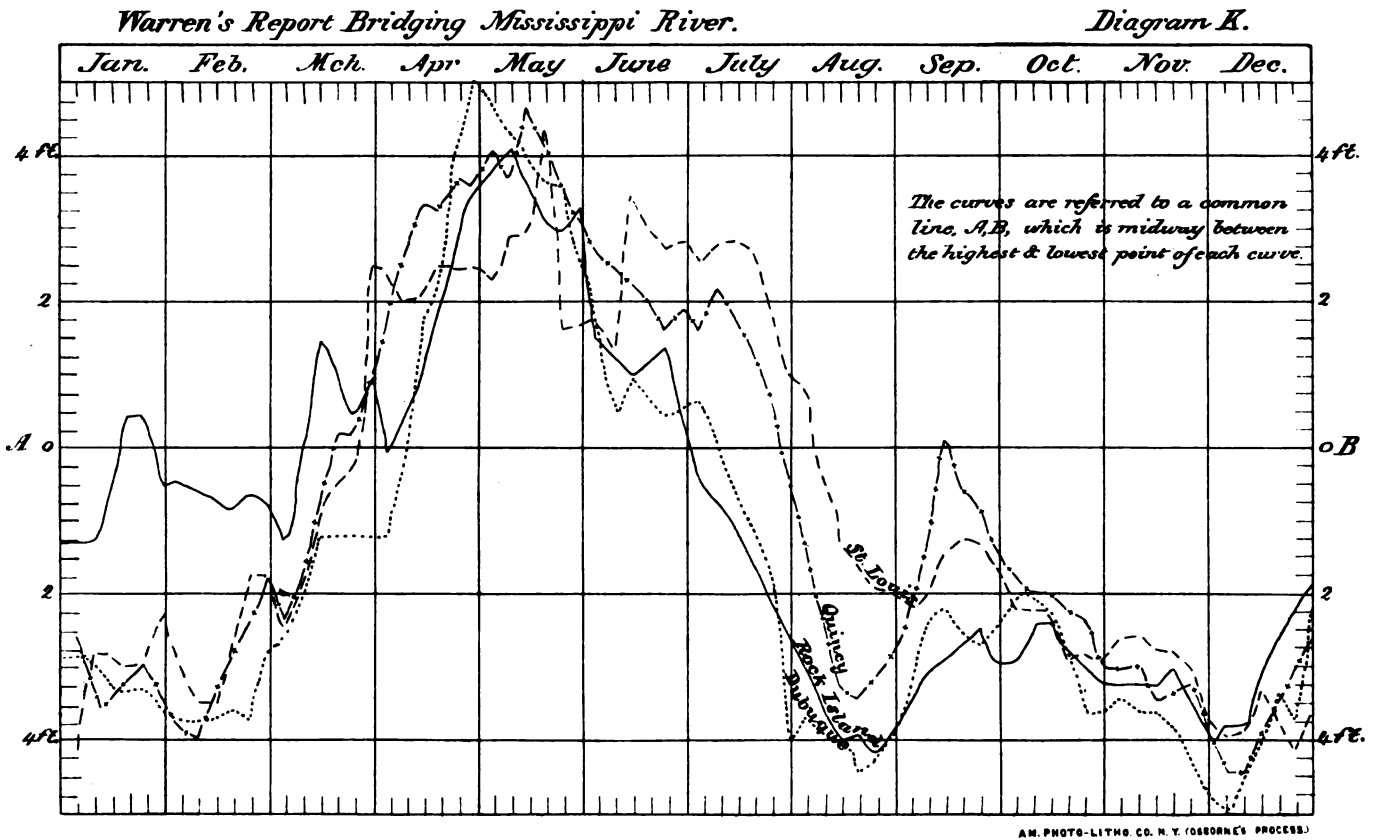

Warren's Report Bridging Mississippi River.
Diagram H.
Jan.
Feb.
Mch.
Apr:
May
June
July
Aug.
Sept.
Oct.
Nov:
Dec.
4ft.
2
A 0
2
4ft.
St Louis
Rock Island
The curves are referred to a common line A,B, which is midway between the highest & lowest point of each curve.
4ft.
2
0 B
2
4ft.
AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS.)

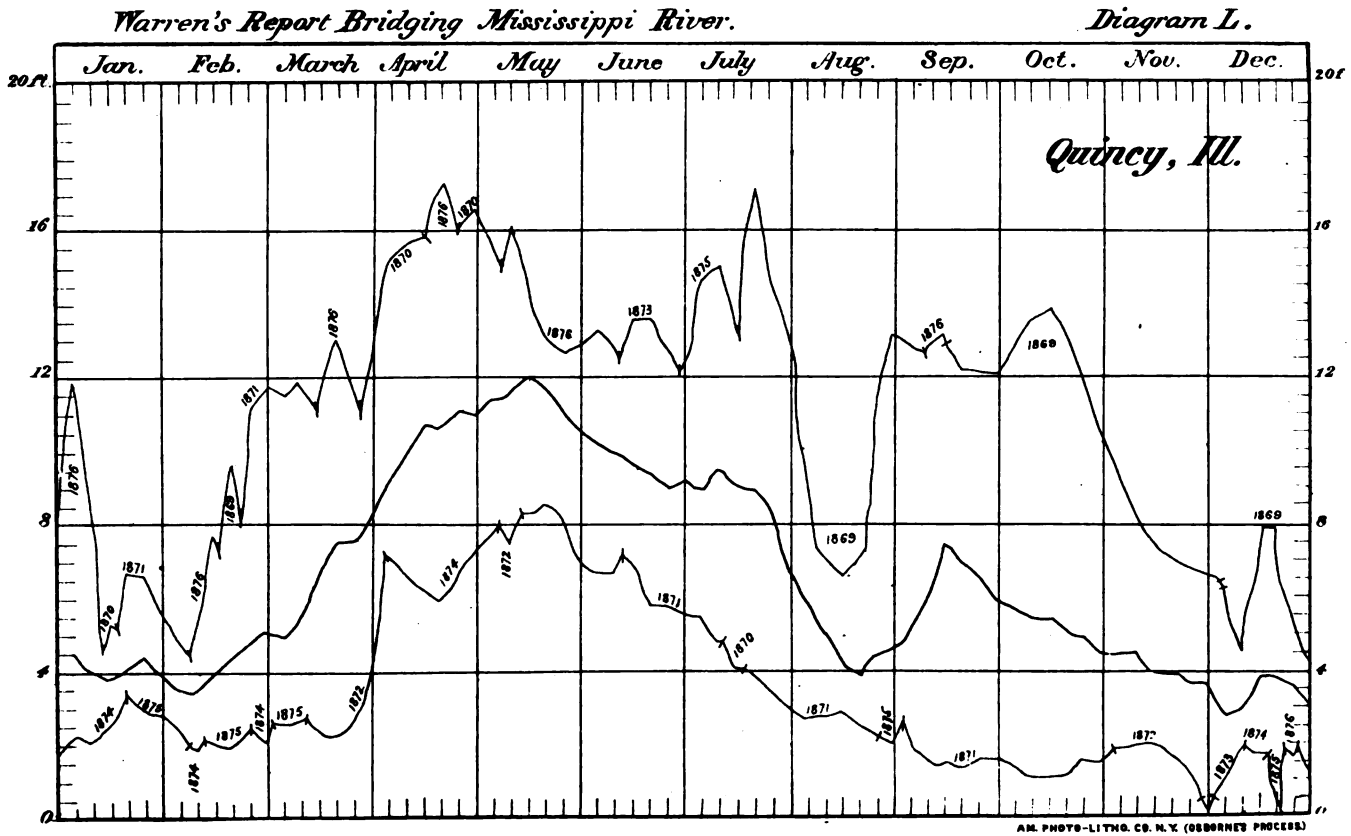
Warren's Report Bridging Mississippi River. *Diagram I.*



AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS.)


Warren's Report Bridging Mississippi River.
Diagram J.
Rock Island, Ill.
Jan.
Feb.
Mar.
April
May
June
July
Aug.
Sep.
Oct.
Nov.
Dec.
20 ft.
16
12
8
4
0
AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS)


Warren's Report Bridging Mississippi River.
Diagram K.
Jan.
Feb.
Mch.
Apr.
May
June
July
Aug.
Sep.
Oct.
Nov.
Dec.
4ft.
2
A o
2
4ft.
4ft.
2
o B
2
4ft.
The curves are referred to a common line, A,B, which is midway between the highest & lowest point of each curve.
St. Louis
Quincy
Rock Island
Dubuque
AM. PHOTO-LITHO. CO. N. Y. (OSBORNE'S PROCESS.)


Warren's Report Bridging Mississippi River.
Diagram L.
Jan.
Feb.
March
April
May
June
July
Aug.
Sep.
Oct.
Nov.
Dec.
20 ft.
16
12
8
4
0
Quincy, Ill.
AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS)

gauge observations for the period of 8 years (January 1, 1869, to December 31, 1876), at Quincy and Dubuque (normal parts of the river), with those at Saint Louis and Rock Island.

As in the preceding case the Saint Louis gauge-readings have been simply divided by 2, and the midway point of all made common on the diagram (diagram K). This diagram itself shows everything that can be described in words, and only a few points will be noted. First, we see that the stand of the gauge at Rock Island, near mid-height during the months of January and February, is anomalous and does not agree with places above and below it, and must be due to local ice gorgings, and that a great uniformity of relative conditions during these months exists at Dubuque, Quincy, and Saint Louis, and generally high water and low water exist at the same time all along the valley, which is a most useful condition for navigation. Second, we see that the high water in April and May occur at the uppermost place first and succeed in order of time regularly downward, showing that this is mainly what is locally known as a "head rise." Third, the June and July rise seems all the way to partake of the character of a head rise, reinforcing a preceding local one and lengthening its period.

There is an exception in the case at Saint Louis, where an intermediate swell of water in excess appears to come from the Missouri.

The September rise occurs all along the valley at nearly the same time, and is consequently due to general rains throughout the region in this month.

One of the increasing advantages of the low-water navigation as we go lower down the river is shown by the curves in August and September, when there is so much business to do. The surface keeps comparatively up at Saint Louis much more than above.

We have added zone Diagram L for Quincy and zone Diagram M for Dubuque for the 8 years similar to those for Saint Louis and Rock Island for 16 years already described.

The gauge observations at other places which we have, do not furnish means for sufficient periods of time to be valuable as such. They will, however, be considered further on in discussing the question of headway.

HEADWAY UNDER BRIDGES.*

In order to consider the question of headway under bridges we have arranged the data from gauge-readings into tables.

1. *Saint Louis tables, &c.*—At Saint Louis we take the number of days when the river in each month stood as follows: between zero (low water) and 5 feet, between 5 and 10 feet, and so on. This interval, 5 feet, was taken by the board of engineers on the Saint Louis bridge (see Annual Report of Chief of Engineers for 1874, pp. 645–648), and we have followed it, because we could thus continue the same comparisons, and make available the data there given. That data embraces the period from 1861 to 1873, and we have added to it the data for the years 1874, '75, '76.

All these data are given in this report in *Table A*, year by year; the intervals of 5 feet are placed in the first left-hand column; the months at the heads of the columns, and the number of days in the body of the column. From it we see, for example, that in the month of January, 1861, there were 31 days when the river was between zero (low water)

* The tables in the report of the board show the number of days the river was not below a given stage; but the consolidated Table H of the report does not show anything about the periods of headway under the bridge, and is therefore very misleading, owing to the errors in its construction.

and 5 feet above. In February, 1861, the river was 15 days between 5 and 10 feet above low water, and 13 days between 10 and 15 feetabove low water, and so on for each month in each year.

TABLE A.—SAINT LOUIS.

1861.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0- 5	31	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	7	38
5-10	.....	15	.....	.....	.....	.....	.....	22	4	15	30	24	110
10-15	.....	13	4	.....	.....	.....	8	9	26	16	.....	.....	76
15-20	.....	.....	27	19	18	30	18	.....	.....	.....	.....	.....	112
20-25	.....	.....	.....	11	10	.....	5	.....	.....	.....	.....	.....	26
25-30	.....	.....	.....	.....	3	.....	.....	.....	.....	.....	.....	.....	3

1862.

0- 5	7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3	10
5-10	16	27	.....	.....	.....	.....	.....	.....	4	.....	28	24	99
10-15	8	1	18	.....	.....	.....	.....	28	26	31	2	4	118
15-20	.....	.....	13	2	.....	20	19	3	.....	.....	.....	.....	57
20-25	.....	.....	.....	9	19	10	12	.....	.....	.....	.....	.....	50
25-30	.....	.....	.....	10	11	.....	.....	.....	.....	.....	.....	.....	21
30-35	.....	.....	.....	9	1	.....	.....	.....	.....	.....	.....	.....	10

1863.

0- 5	.....	.....	.....	.....	.....	.....	.....	.....	7	31	18	31	87
5-10	6	8	.....	.....	.....	12	25	29	23	.....	12	.....	115
10-15	23	7	11	19	31	18	6	2	.....	.....	.....	.....	117
15-20	2	13	20	11	.....	.....	.....	.....	.....	.....	.....	.....	46

1864.

0- 5	8	.....	.....	.....	.....	.....	.....	12	30	31	23	12	116
5-10	23	29	21	9	2	6	7	19	.....	.....	7	19	142
10-15	.....	.....	10	15	16	24	24	.....	.....	.....	.....	.....	89
15-20	.....	.....	.....	6	13	.....	.....	.....	.....	.....	.....	.....	19

1865.

0- 5	31	12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	43
5-10	.....	13	.....	.....	.....	.....	.....	.....	.....	5	12	28	58
10-15	.....	2	12	.....	9	19	.....	.....	24	26	18	3	113
15-20	.....	1	18	17	21	11	22	14	6	.....	.....	.....	110
20-25	.....	.....	1	12	1	.....	5	15	.....	.....	.....	.....	34
25-30	.....	.....	.....	1	.....	.....	4	2	.....	.....	.....	.....	7

1866.

5-10	6	19	.....	.....	.....	.....	.....	.....	.....	14	12	22	73
10-15	24	9	12	5	.....	.....	3	31	20	12	18	9	143
15-20	1	.....	16	12	10	26	28	.....	6	5	.....	.....	104
20-25	.....	.....	3	4	21	4	.....	.....	4	.....	.....	.....	36
25-30	.....	.....	.....	9	.....	.....	.....	.....	.....	.....	.....	.....	9

1867.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0- 5	9											24	33
5-10	22	8							18	31	30	7	116
10-15		7	10	6				10	12				45
15-20		2	19	7	6			21					55
20-25		11	2	3	18	22	14						70
25-30				14	7	8	17						46

1868.

0- 5	24	12	2									4	42
5-10	7	17	9					29	30	31	15	27	165
10-15			7	16		12	19	2			15		71
15-20			13	12	12	18	12						67
20-25				2	19								21

1869.

5-10	11	7	14									16	48
10-15	20	17	17	6						2	30	15	107
15-20		4		23	30	9		23	27	29			145
20-25				1	1	21	1	6	3				33
25-30							30	2					32

1870.

5-10	31	28	16				10	29	13	4	14	31	176
10-15			11			18	21	2	17	27	8		104
15-20			4		17	12					8		41
20-25				24	14								38
25-30				6									6

1871.

0- 5	10								21	31	14	13	89
5-10	14	8					8	31	9		16	18	104
10-15	7	15		23	10	22	23						100
15-20		5	22	7	21	8							63
20-25			9										9

1872.

0- 5	16									1	7	26	50
5-10	15	28	29					2	30	30	23	5	162
10-15		1	2	14	5			21					43
15-20				16	16	11	27	8					78
20-25					10	19	4						33

1873.

0- 5											4	3	7
5-10	21	16	11					11	30	31	26	19	165
10-15	10	11	10	5				17				8	61
15-20		1	10	12	16		11	3				1	54
20-25				7	15	26	20						70
25-30				6		2							8

1874.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0– 5	7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	25	32
5–10	16	16	4	.....	.....	.....	.....	28	28	31	30	6	159
10–15	8	12	12	15	26	15	31	3	2	.....	.....	.....	124
15–20	.....	.....	15	15	5	15	.....	.....	.....	.....	.....	.....	50

1875.

0– 5	10	20	1	.....	.....	.....	.....	.....	.....	.....	1	16	48
5–10	21	8	22	.....	.....	.....	.....	.....	.....	17	29	15	112
10–15	.....	.....	8	3	.....	.....	.....	17	11	14	.....	.....	53
15–20	.....	.....	.....	25	18	19	.....	5	19	.....	.....	.....	66
20–25	.....	.....	.....	2	13	11	15	2	.....	.....	.....	.....	43
25–30	.....	.....	.....	.....	.....	.....	16	7	.....	.....	.....	.....	23

1876.

0– 5	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2
5–10	14	14	9	.....	.....	.....	.....	.....	.....	15	6	11	69
10–15	11	13	4	.....	.....	.....	.....	28	7	16	24	20	123
15–20	6	.....	12	.....	5	2	4	3	12	.....	.....	.....	44
20–25	.....	.....	6	15	7	22	9	.....	11	.....	.....	.....	70
25–30	.....	.....	.....	15	13	6	18	.....	.....	.....	.....	.....	52
30–35	.....	.....	.....	.....	6	.....	.....	.....	.....	.....	.....	.....	6

For convenience of comprehending and comparing the stages of the river for the same month in all the years observed, Table B is constructed from Table A. The heights are given in the left-hand column as in A, the years at the heads of the columns, and the number of days in the body of the table. The monthly averages of numbers of days are in the right-hand column. From this we see, for example, that although in January in 1861 and in 1865 the river was within 5 feet of low water all the month, there were 6 years out of 16 that it did not fall as low as 5 feet above low water; that on the average it was but $9\frac{6}{10}$ days when the river was between 0 and 5 feet; that in these years the river was more than 20 feet above low water in January, and only 3 of them where it was above 15 feet, and so on.

TABLE B.—SAINT LOUIS.

January.

	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0– 5	31	7	6	8	31	....	9	24	....	....	10	16	....	7	10	....	9.7
5–10	....	16	6	23	....	6	22	7	11	31	14	15	21	16	21	14	13.9
10–15	....	8	23	....	....	21	....	....	20	....	7	....	10	8	....	11	6.7
15–20	....	....	2	....	....	4	....	....	....	....	....	....	....	....	....	6	0.7

February.

0– 5	....	....	....	....	12	....	....	12	....	....	....	....	....	....	20	2	2.8
5–10	15	27	8	29	13	19	8	17	7	28	8	28	16	16	8	14	16.3
10–15	13	1	7	....	2	9	7	....	17	....	15	1	11	12	....	13	6.8
15–20	....	....	13	....	1	....	2	....	4	....	5	....	1	....	....	....	1.6
20–25	....	....	....	....	....	....	11	....	....	....	....	....	....	....	....	....	0.7

March.

	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0– 5	....	....	....	....	....	....	....	2	....	....	....	....	....	....	1	....	0.2
5–10	....	....	....	21	....	....	....	9	14	16	....	29	11	4	22	9	8.4
10–15	4	18	11	10	12	12	10	7	17	11	....	2	10	12	8	14	9.3
15–20	27	13	20	....	18	16	19	13	....	4	22	....	10	15	....	12	11.8
20–25	....	....	....	....	1	3	2	....	....	....	9	....	....	....	....	6	1.3

April.

5–10	....	....	....	9	....	....	....	....	....	....	....	....	....	....	....	....	0.6
10–15	....	....	19	15	....	5	6	16	6	....	23	14	5	15	3	....	7.9
15–20	19	2	11	6	17	12	7	12	23	....	7	16	12	15	25	....	11.4
20–25	11	9	....	....	12	4	3	2	1	24	....	....	7	....	2	15	5.6
25–30	....	10	....	....	1	9	14	....	....	6	....	....	6	....	....	15	3.8
30–35	....	9	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.6

May.

5–10	....	....	....	2	....	....	....	....	....	....	....	....	....	....	....	....	0.1
10–15	....	....	31	16	9	....	....	....	....	....	10	5	....	26	....	....	6.1
15–20	18	....	....	13	21	10	6	12	30	17	21	16	16	5	18	5	13.0
20–25	10	19	....	....	1	21	18	19	1	14	....	10	15	....	13	7	9.2
25–30	3	11	....	....	....	....	7	....	....	....	....	....	....	....	....	13	2.1
30–35	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	6	0.4

June.

5–10	....	....	12	6	....	....	....	....	....	....	....	....	....	....	....	....	1.1
10–15	....	....	18	24	19	....	....	12	....	18	22	....	....	15	....	....	8.0
15–20	30	20	....	....	11	26	....	18	9	12	8	11	....	15	19	2	11.3
20–25	....	10	....	....	....	4	22	....	21	....	....	19	28	....	11	22	8.6
25–30	....	....	....	....	....	....	8	....	....	....	....	....	2	....	....	6	1.0

July.

5–10	....	....	25	7	....	....	....	....	....	10	8	....	....	....	....	....	3.1
10–15	8	....	6	24	....	3	....	19	....	21	23	....	....	31	....	....	8.4
15–20	18	19	....	....	22	28	....	12	....	....	....	27	11	....	....	4	8.8
20–25	5	12	....	....	5	....	14	....	1	....	....	4	20	....	15	9	5.3
25–30	....	....	....	....	4	....	17	....	30	....	....	....	....	....	16	18	5.3

August.

0– 5	....	....	....	12	....	....	....	....	....	....	....	....	....	....	....	....	0.7
5–10	22	....	29	19	....	....	....	29	....	29	31	2	11	28	....	....	12.5
10–15	9	28	2	....	....	31	10	2	....	2	....	21	17	3	17	28	10.6
15–20	....	3	....	....	14	....	21	....	23	....	....	8	3	....	5	3	5.0
20–25	....	....	....	....	15	....	....	....	6	....	....	....	....	....	2	....	1.5
25–30	....	....	....	....	2	....	....	....	2	....	....	....	....	....	7	....	0.7

September.

0– 5	....	....	7	30	....	....	....	....	....	....	21	....	....	....	....	....	3.6
5–10	4	4	23	....	....	....	18	30	....	13	9	30	30	28	....	....	11.8
10–15	26	26	....	....	24	20	12	....	....	17	....	....	....	2	11	7	9.1
15–20	....	....	....	....	6	6	....	....	27	....	....	....	....	....	19	12	4.4
20–25	....	....	....	....	....	4	....	....	3	....	....	....	....	....	....	11	1.1

October.

	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 5	....	....	31	31	....	....	....	....	....	....	31	1	....	....	....	....	5.4
5-10	15	....	....	....	5	14	31	31	....	4	....	30	31	31	17	15	9.0
10-15	16	31	....	....	26	12	....	....	2	27	....	....	....	....	14	16	19.0
15-20	....	....	....	....	....	5	....	....	29	....	....	....	....	....	....	....	2.1

November.

0- 5	..	....	18	23	....	....	....	....	....	....	14	7	4	.	1	....	4.2
5-10	30	28	12	7	12	12	30	15	..	14	16	23	26	30	29	6	18.1
10-15	....	2	..	....	18	18	....	15	30	8	....	....	....	....	..	24	7.2
15-20	....	..	....	..	....	..	..	....	..	8	..	....	....	....	....	....	0.5

December.

0- 5	7	3	31	12	.	..	24	4	....	..	13	26	3	25	16	..	10.2
5-10	24	24	....	19	28	22	7	27	16	31	18	5	19	6	15	11	17.0
10-15	....	4	....	..	3	9	....	....	15	..	....	....	8	....	..	20	3.7
15-20	..	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	0.1

This table and Table C, described and given below, enable us to consider and decide what season to choose, to have the stage of water best suited to any engineering or navigation purposes.

To enable a ready comparison of all the *monthly averages* of numbers of days that the river was at any stage to be made, *Table C* has been constructed from the averages in Table B. The heights are here given at the heads of the columns and the average number of days in the body of the table.

TABLE C.—SAINT LOUIS.

Monthly averages for sixteen years, from 1861 *to* 1876 *inclusive, of number of days the river-surface at Saint Louis was at the height indicated by the figures at the heads of the columns.*

Months.	0 to 5 feet.	5 to 10 feet.	10 to 15 feet.	15 to 20 feet.	20 to 25 feet.	25 to 30 feet.	30 to 35 feet.
January	9.7	13.9	6.7	0.75	.....	.....	.....
February	2.8	16.3	6.8	1.6	0.7	.....	.....
March	0.2	8.4	9.3	11.8	1.3	.....	.....
April	.....	0.6	7.9	11.4	5.6	3.8	0.6
May	.....	0.1	6.1	13.0	9.2	2.1	0.4
June	.....	1.1	8.0	11.3	8.6	1.0	.....
July	.....	3.1	8.4	8.8	5.3	5.3	.....
August	0.7	12.5	10.6	5.0	1.5	0.7	.....
September	3.6	11.8	9.1	4.4	1.1	.....	.....
October	5.9	14.0	9.0	2.1	.....	.....	.....
November	4.2	18.1	7.2	0.5	.....	.....	.....
December	10.2	17.1	3.7	0.1	.....	.....	.....
Yearly average	37.3	117.0	92.8	70.7	33.3	12.9	1.0

To compare each year with the others and with the averages of all the years, *Table D* is constructed from the "Totals" of the columns in *Table A*. The figures in the body of the table are number of days.

An examination of this table shows how often during the period given that the average was reached, and how often and how many days were above and below the average in different years.

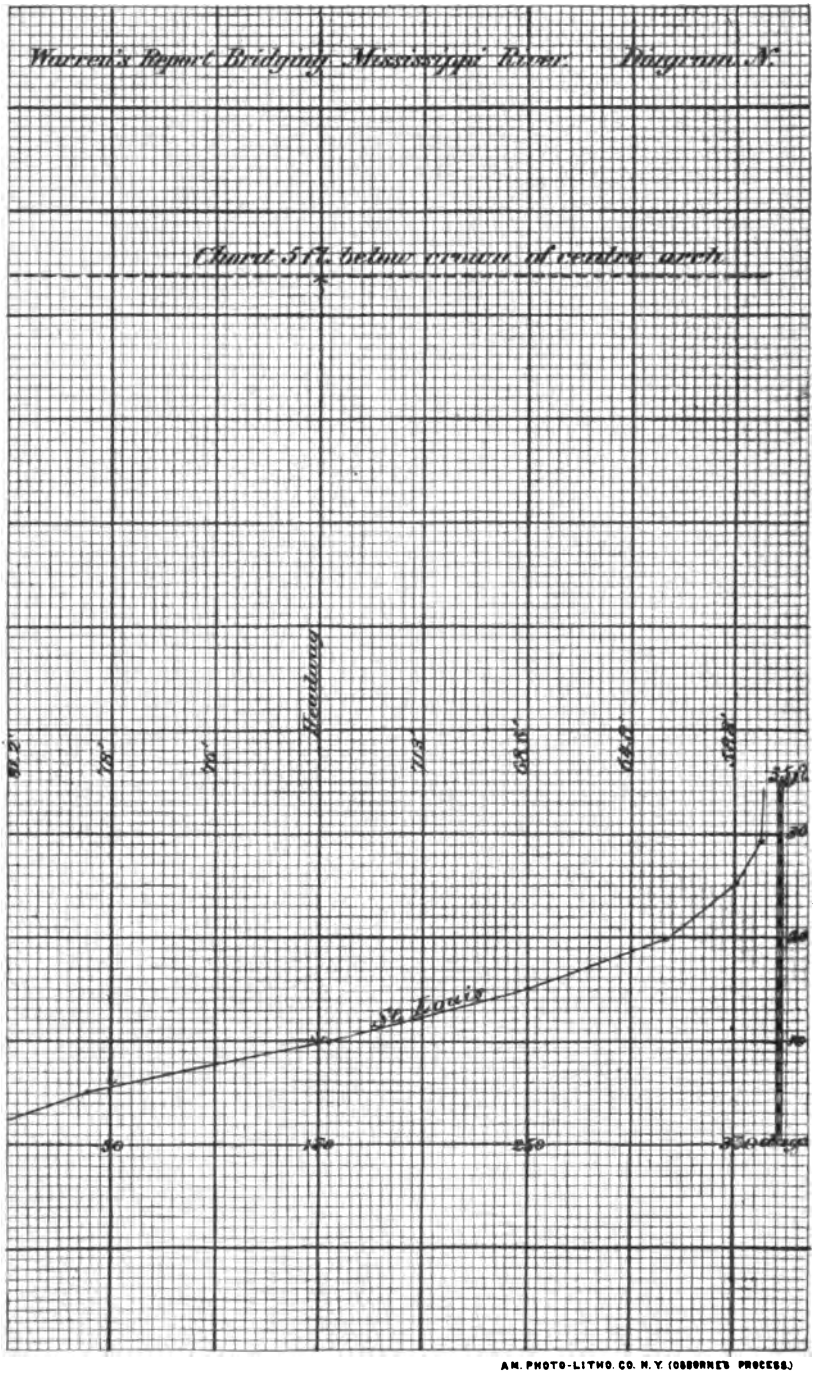

Warren's Report Bridging Mississippi River. Diagram N°.
Chart 3 ft. below crown of centre arch.
Reading
St Louis
50
150
250
AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS)

TABLE D.—SAINT LOUIS.

Table, by years, of number of days the river-surface at Saint Louis, Mo., was at the heights indicated by the figures at the heads of the columns.

Years.	0 to 5 feet.	5 to 10 feet.	10 to 15 feet.	15 to 20 feet.	20 to 25 feet.	25 to 30 feet.	30 to 35 feet.
1861	38	110	76	112	26	3	.....
1862	10	99	118	57	50	21	10
1863	87	115	117	46	.....	.....	.....
1864	116	142	89	19	.....	.....	.....
1865	43	58	113	110	34	7	.....
1866	.....	73	143	104	36	9	.....
1867	33	116	45	55	70	46	.....
1868	42	165	71	67	21	.....	.....
1869	.....	48	107	145	33	32	.....
1870	.....	176	104	41	38	6	.....
1871	89	104	100	63	9	.....	.....
1872	50	162	43	78	33	.....	.....
1873	7	165	61	54	70	8	.....
1874	32	159	124	50	.....	.....	.....
1875	48	112	53	86	43	23	.....
1876	2	69	123	44	70	52	6
Yearly average	37.3	117.0	92.9	70.7	33.3	12.9	1.0

In order to present one general table and curve exhibiting the matter of headway generally, we get from Table D an average of the following:

	Between—						
	0 and 5 feet.	5 and 10 feet.	10 and 15 feet.	15 and 20 feet.	20 and 25 feet.	25 and 30 feet.	30 and 35 feet.
Number of days	37.3	154.3	247.3	317.9	351.2	364.1	365.1

From these data the curve in Diagram N is constructed, with the numbers of days as abscissas, and the numbers 5, 10, 15, &c., as ordinates.

If, now, we take 50 feet above the city directrix at Saint Louis as the height of the lowest part of a bridge (the directrix being 33.8 above low water), we shall have the bridge represented on the diagram by the horizontal line 83.8 feet above zero. For convenience we have placed numbers giving the vertical heights from the bridge line downward on the right-hand side of the diagram. If we know the height of a vessel, this diagram will at once tell us the average number of days she cannot pass under it. Thus, if she required 75 feet headway, we see that there are only 125 days on the average when the river would not be too high. The months of the year when this height is most frequent are shown in *Table C.*

The many questions which may arise, it is believed, can all be as thoroughly considered as our knowledge of facts will permit, by consulting and studying the foregoing tables and diagrams.

2. *Rock Island tables, &c.*—The tables of observations at this place are for comparison of conditions existing at Rock Island with those at Saint Louis as affecting high bridges.

We leave out the gauge observations for 1860, because they were not recorded at the latter place. The difference between extremes of rise and fall are about half at Rock Island of what they are at Saint Louis. We therefore make up our *tables* for intervals of only two feet instead of five. In this way the following tables, A, B, C, are constructed for Rock Island the same as for Saint Louis. And the same explanations, as to construction, &c., are applicable, and so we do not repeat them.

TABLE A.—ROCK ISLAND.

1861.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0- 2	.....	.....	.....	.....	.....	.....	.....	9	11	.....	.....	4	24
2- 4	.....	.....	.....	.....	.....	.....	11	22	19	7	30	22	111
4- 6	.....	.....	9	8	.....	4	20	.....	.....	24	.....	1	66
6- 8	13	23	13	5	.....	4	.....	.....	.....	.....	.....	.....	58
8-10	14	5	4	3	.....	9	.....	.....	.....	.....	.....	3	38
10-12	4	.....	2	4	20	13	.....	.....	.....	.....	.....	1	44
12-14	.....	.....	3	4	9	.....	.....	.....	.....	.....	.....	.....	16
14-16	.....	.....	.....	6	2	.....	.....	.....	.....	.....	.....	.....	8

1862.

0- 2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	7	17	24
2- 4	.....	.....	.....	.....	.....	.....	4	31	30	6	23	14	108
4- 6	.....	.....	.....	.....	.....	12	24	.....	.....	25	.....	.....	61
6- 8	.....	16	17	.....	.....	6	3	.....	.....	.....	.....	.....	42
8-10	31	12	8	10	5	6	.....	.....	.....	.....	.....	.....	72
10-12	.....	.....	5	11	7	6	.....	.....	.....	.....	.....	.....	29
12-14	.....	.....	1	9	6	.....	.....	.....	.....	.....	.....	.....	16
14-16	.....	.....	.....	.....	13	.....	.....	.....	.....	.....	.....	.....	13

1863.

0- 2	6	.....	.....	.....	.....	9	31	19	13	31	10	31	150
2- 4	25	7	11	.....	.....	10	.....	12	14	.....	20	.....	99
4- 6	.....	15	12	8	12	11	.....	.....	3	.....	.....	.....	61
6- 8	.....	6	8	19	11	.....	.....	.....	.....	.....	.....	.....	44
8-10	.....	.....	.....	3	8	.....	.....	.....	.....	.....	.....	.....	11

1864.

0- 2	.....	.....	.....	.....	.....	24	31	31	30	31	30	7	184
2- 4	31	24	15	8	11	6	.....	.....	.....	.....	.....	9	104
4- 6	.....	.....	13	22	20	.....	.....	.....	.....	.....	.....	15	70
6- 8	.....	2	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	5
8-10	.....	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3

1865.

0- 2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4	4
2- 4	31	18	5	.....	.....	23	.....	6	9	26	15	8	141
4- 6	.....	5	8	.....	15	7	14	25	21	5	15	19	134
6- 8	.....	2	3	12	4	.....	17	.....	.....	.....	.....	.....	38
8-10	.....	1	11	8	6	.....	.....	.....	.....	.....	.....	.....	26
10-12	.....	2	4	10	6	.....	.....	.....	.....	.....	.....	.....	22

1866.

0- 2	.....	.....	.....	.....	.....	.....	.....	.....	.....	20	.....	.....	20
2- 4	10	26	1	4	.....	6	23	15	30	11	30	21	177
4- 6	21	2	3	2	2	24	8	10	.....	.....	.....	5	77
6- 8	.....	.....	6	4	6	.....	.....	6	.....	.....	.....	.....	22
8-10	.....	.....	6	14	3	.....	.....	.....	.....	.....	.....	1	24
10-12	.....	.....	7	4	4	.....	.....	.....	.....	.....	.....	.....	15
12-14	.....	.....	8	2	8	.....	.....	.....	.....	.....	.....	4	22
14-16	.....	.....	.....	.....	8	.....	.....	.....	.....	.....	.....	.....	8

1867.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0- 2												5	5
2- 4									23	31	30	7	91
4- 6								3	7			5	15
6- 8	8	12	18	5			3	10				14	70
8-10	14	5	13	20	17	16	7	10					102
10-12	9	10		5	11	4	15	8					62
12-14		1			3	6	6						16
14-16						4							4

1868.

0- 2							7	19	16				42
2- 4							18	12	14	31	9	12	96
4- 6					3	27	6				19	9	64
6- 8	31	29	17	26	15	3					2	8	131
8-10			10	4	13							2	29
10-12			1										1
12-14			2										2
14-16													
16-18			1										1

1869.

0- 2													
2- 4		1	14									19	34
4- 6		11	16	2		11		19			17	12	88
6- 8	4	8	1	11	2	16	20	10	13		12		97
8-10	20	5		12	10	8	11	2	16	10	1		90
10-12	6	3		5	19				1	12			46
12-14	1									9			10

1870.

0- 2												1	1
2- 4	2						19	19			4	20	64
4- 6	8					7	12	12	5	31	26	10	111
6- 8	7					12			12				31
8-10		6	3	4	19	11			13				56
10-12	3	16	15	8	5								47
12-14	11	6	4	4	4								29
14-16			5	5	3								13
16-18			4	9									13

1871.

0- 2								7	29	26	6	1	69
2- 4	12						25	24	1	5	24	5	96
4- 6	13	8		8		18	6					25	78
6- 8	6	16	17	9	1	12							61
8-10		3	14	13	9								39
10-12					12								12
12-14		1			9								10

1872.

0- 2									4	9	23		36
2- 4	13	25	5	3			3	30	26	22	5		132
4- 6	18	4	24	18	7	10	28	1			1	15	126
6- 8			1	9	13	15					1	16	55
8-10			1		11	5							17

1873.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0- 2	.....	.....	.....	.....	.....	.....	.....	.....	22	5	9	7	43
2- 4	.....	.....	.....	.....	.....	.....	.....	28	8	26	21	13	96
4- 6	31	28	16	4	.....	.....	5	3	.....	.....	.....	6	93
6- 8	.....	.....	5	21	1	5	6	.....	.....	.....	.....	4	42
8-10	.....	.....	8	5	16	4	10	.....	.....	.....	.....	1	44
10-12	.....	.....	2	.....	12	19	10	.....	.....	.....	.....	.....	43
12-14	.....	.....	.....	.....	2	2	.....	.....	.....	.....	.....	.....	4

1874.

0- 2	.....	.....	.....	.....	.....	.....	.....	11	.....	.....	.....	15	26
2- 4	.....	.....	.....	.....	1	.....	.....	19	24	8	19	16	87
4- 6	.....	4	7	25	.....	25	6	1	6	23	11	.....	108
6- 8	7	24	14	5	24	5	25	.....	.....	.....	.....	.....	104
8-10	23	.....	1	.....	6	.....	.....	.....	.....	.....	.....	.....	30
10-12	1	.....	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	5
12-14	.....	.....	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	3
14-16	.....	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	2

1875.

0- 2	.....	.....	.....	.....	.....	.....	.....	25	5	.....	9	11	50
2- 4	4	1	12	.....	.....	.....	11	6	4	27	21	14	100
4- 6	7	27	16	.....	.....	.....	7	.....	8	4	.....	4	73
6- 8	16	.....	1	.....	.....	29	13	.....	13	.....	.....	2	74
8-10	4	.....	2	21	19	1	.....	.....	.....	.....	.....	.....	47
10-12	.....	.....	.....	5	9	.....	.....	.....	.....	.....	.....	.....	14
12-14	.....	.....	.....	4	3	.....	.....	.....	.....	.....	.....	.....	7

1876.

0- 2	2	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4
2- 4	20	16	7	.....	.....	.....	5	31	.....	26	30	5	140
4- 6	9	6	8	4	.....	.....	9	.....	22	5	.....	26	89
6- 8	.....	5	7	3	.....	5	3	.....	8	.....	.....	.....	31
8-10	.....	.....	9	5	.....	16	11	.....	.....	.....	.....	.....	41
10-12	.....	.....	.....	3	16	4	8	.....	.....	.....	.....	.....	26
12-14	.....	.....	.....	15	15	5	.....	.....	.....	.....	.....	.....	35

TABLE B.—ROCK ISLAND.

January.

Heights in feet.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 2	....	....	6	....	....	....	....	....	....	....	....	....	....	....	....	....	0.5
2- 4	....	....	25	31	31	10	....	....	....	2	12	13	....	....	4	20	9.2
4- 6	....	....	....	....	....	21	....	....	....	8	13	18	31	....	7	9	6.7
6- 8	13	....	....	....	....	....	8	31	4	7	6	....	....	7	16	....	5.8
8-10	14	31	....	....	....	....	14	....	20	....	....	....	....	23	4	....	6.6
10-12	4	....	....	....	....	....	9	....	6	3	....	....	....	1	....	....	1.4
12-14	....	....	....	....	....	....	....	....	1	11	....	....	....	....	....	....	0.8

February.

0- 2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	0.1
2- 4	....	....	7	24	18	26	....	....	1	....	....	25	....	....	1	16	7.4
4- 6	....	....	15	....	5	2	....	....	11	....	8	4	28	4	27	6	6.9
6- 8	23	16	6	2	2	....	12	29	8	....	16	....	....	24	....	5	8.9
8-10	5	12	....	3	1	....	5	....	5	6	3	....	....	....	....	....	2.5
10-12	....	....	....	....	2	....	10	....	3	16	....	....	....	....	....	....	1.9
12-14	....	....	....	....	....	....	1	....	....	6	1	....	....	....	....	....	0.5

March.

Heights in feet.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....
2- 4	....	....	11	15	5	1	....	....	14	....	....	5	....	....	12	7	4.4
4- 6	9	....	12	13	8	3	....	....	16	....	....	24	16	7	16	8	8.2
6- 8	13	17	8	3	3	6	18	17	1	....	17	1	5	14	1	7	8.2
8-10	4	8	....	....	11	6	13	10	....	3	14	1	8	1	2	9	5.6
10-12	2	5	....	....	4	7	....	1	....	15	....	....	2	4	....	....	2.5
12-14	3	1	....	....	....	8	....	2	....	4	....	....	....	3	....	....	1.3
14-16	....	....	....	....	....	....	....	....	....	5	....	....	....	2	....	....	0.4
16-18	....	....	....	....	....	....	....	1	....	4	....	....	....	....	....	....	0.3

April.

0- 2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....
2- 4	....	....	....	8	....	4	....	....	....	....	....	3	....	....	....	....	0.9
4- 6	8	....	8	22	....	2	....	....	2	....	8	18	4	25	....	4	6.3
6- 8	5	....	19	....	12	4	5	26	11	....	9	9	21	5	....	3	8.1
8-10	3	10	3	....	8	14	20	4	12	4	13	....	5	....	21	5	7.6
10-12	4	11	....	....	10	4	5	....	5	8	....	....	....	....	5	3	3.4
12-14	4	9	....	....	....	2	....	....	....	4	....	....	....	....	4	15	2.4
14-16	6	....	....	....	....	....	....	....	....	5	....	....	....	....	....	....	0.7
16-18	....	....	....	....	....	....	....	....	....	9	....	....	....	....	....	....	0.6

May.

0- 2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....
2- 4	....	....	....	11	....	....	....	....	....	....	....	....	....	1	....	....	0.8
4- 6	....	....	12	20	15	2	....	3	....	....	....	7	....	....	....	....	3.7
6- 8	....	....	11	....	4	6	....	15	2	....	1	13	1	24	....	....	4.8
8-10	....	5	8	....	6	3	17	13	10	19	9	11	16	6	19	....	8.9
10-12	20	7	....	....	6	4	11	....	19	5	12	....	12	....	9	16	7.5
12-14	9	6	....	....	....	8	3	....	....	4	9	....	2	....	3	15	3.7
14-16	2	13	....	....	....	8	....	....	....	3	....	....	....	....	....	....	1.6

June.

0- 2	....	....	9	24	....	....	....	....	....	....	....	....	....	....	....	....	2.1
2- 4	....	....	10	6	23	6	....	....	....	....	....	....	....	....	....	....	2.7
4- 6	4	12	11	....	7	24	....	27	11	7	18	10	....	25	....	....	9.8
6- 8	4	6	....	....	....	....	....	3	16	12	12	15	5	5	29	5	7.0
8-10	9	6	....	....	....	....	16	....	3	11	....	5	4	....	1	16	4.4
10-12	13	6	....	....	....	....	4	....	....	....	....	....	19	....	....	4	2.9
12-14	....	....	....	....	....	....	6	....	....	....	....	....	2	....	....	5	0.3
14-16	....	....	....	....	....	....	4	....	....	....	....	....	....	....	....	....	0.8

July.

0- 2	....	....	31	31	....	....	....	7	....	....	....	....	....	....	....	....	4.3
2- 4	11	4	....	....	....	23	....	18	....	19	25	3	....	....	11	5	7.4
4- 6	20	24	....	....	14	8	....	6	....	12	6	28	5	6	7	9	9.1
6- 8	....	3	....	....	17	....	3	....	20	....	....	....	6	25	13	3	5.6
8-10	....	....	....	....	....	....	7	....	11	....	....	....	10	....	....	11	2.4
10-12	....	....	....	....	....	....	15	....	....	....	....	....	10	....	....	3	1.7
12-14	....	....	....	....	....	....	6	....	....	....	....	....	....	....	....	....	0.4

August.

0- 2	9	....	19	31	....	....	....	19	....	....	7	....	....	11	25	....	7.6
2- 4	22	31	12	....	6	15	....	12	....	19	24	30	28	19	6	31	16.0
4- 6	....	....	....	....	25	10	3	....	19	12	....	1	3	1	....	....	4.6
6- 8	....	....	....	....	....	6	10	....	10	....	....	....	....	....	....	....	1.6
8-10	....	....	....	....	....	....	10	....	2	....	....	....	....	....	....	....	0.8
10-12	....	....	....	....	....	....	8	....	....	....	....	....	....	....	....	....	0.5

September.

Heights in feet.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 2	11	...	13	30	....	....	....	16	....	....	29	4	22	....	5	....	8.1
2- 4	19	30	14	....	9	30	23	14	....	....	1	26	8	24	4	....	12.6
4- 6	....	....	3	....	21	....	7	....	....	5	....	....	....	6	8	22	4.5
6- 8	....	....	....	....	....	....	....	....	13	12	....	....	....	....	13	8	2.9
8-10	....	....	....	....	....	....	....	....	16	13	....	....	....	....	....	....	1.8
10-12	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	0.1

October.

0- 2	...	...	31	31	....	20	....	....	....	....	26	9	5	....	....	....	7.6
2- 4	7	6	....	....	26	11	31	31	....	....	5	22	26	8	27	26	14.1
4- 6	24	25	....	....	5	....	....	....	....	31	....	....	....	23	4	5	7.3
6- 8	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....
8-10	....	....	....	....	....	....	....	....	10	....	....	....	....	....	....	....	0.6
10-12	....	....	....	....	....	....	....	....	12	....	....	....	....	....	....	....	0.8
12-14	....	....	....	....	....	....	....	....	9	....	....	....	....	....	....	....	0.6

November.

0- 2	....	7	10	30	....	....	....	....	....	....	6	23	9	....	9	...	5.9
2- 4	30	23	20	....	15	30	30	9	....	4	24	5	21	19	21	30	17.5
4- 6	....	....	....	....	15	....	....	19	17	26	....	1	....	11	....	....	5.6
6- 8	....	....	....	....	....	....	....	2	12	....	....	1	....	....	....	....	0.9
8-10	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	0.1

December.

0- 2	4	17	31	7	4	....	5	....	....	1	1	....	7	15	11	...	6.4
2- 4	23	14	....	9	8	21	7	12	19	20	5	....	13	16	14	5	11.6
4- 6	1	....	....	15	19	5	5	9	12	10	25	15	6	....	4	26	9.5
6- 8	....	....	....	....	....	....	14	8	....	....	....	16	4	...	2	...	2.7
8-10	3	....	....	....	....	1	....	2	....	....	....	....	1	....	....	....	0.4
10-12	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.1
12-14	....	....	....	....	....	4	....	....	....	....	....	....	....	....	....	....	0.3

TABLE C.—ROCK ISLAND.

Monthly averages for 16 *years, from* 1861 *to* 1876, *inclusive, of number of days the river-surface at Rock Island, Ill., was at the height indicated by the figures at the head of the columns.*

	0 to 2 feet.	2 to 4 feet.	4 to 6 feet.	6 to 8 feet.	8 to 10 feet.	10 to 12 feet.	12 to 14 feet.	14 to 16 feet.	16 to 18 feet.
January	0.5	9.2	6.7	5.8	6.6	1.4	0.7	.....	.....
February	0.1	7.4	6.9	8.9	2.5	1.9	0.5	.....	.....
March	.....	4.4	8.2	8.2	5.6	2.5	1.3	0.4	0.3
April	.....	0.9	6.3	8.1	7.6	3.4	2.4	0.7	0.6
May	.....	0.8	3.7	4.8	8.9	7.6	3.7	1.6	.....
June	2.1	2.8	9.7	7.0	4.4	2.9	0.8	0.3	.....
July	4.3	7.4	9.1	5.6	2.4	1.7	0.4	.....	.....
August	7.6	16.0	4.6	1.6	0.8	0.5	.....	.....	.....
September	8.1	12.6	4.5	2.9	1.8	0.1	.....	.....	.....
October	7.6	14.1	7.3	.....	0.6	0.8	0.6	.....	.....
November	5.9	17.5	5.6	0.9	0.1	.....	.....	.....	.....
December	6.4	11.6	9.5	2.8	0.4	0.1	0.3	.....	.....
Yearly average	42.6	104.7	82.1	56.6	41.7	22.9	10.6	3.0	0.9

Comparison of conditions at Saint Louis with those at Rock Island, with regard to headway.—There are at least four months (December, January, February, and March,) when the navigation above Rock

Island is uncertain, if not impracticable, on account of ice. We must, therefore, in making the comparison for navigable headway throw out the gauge observations at these two places for this wintry season. In this way we construct the following two tables of yearly means:

TABLE D.—SAINT LOUIS.

Table, by years, of number of days the river's surface at Saint Louis, Mo., was at the heights indicated by the figures at the head of the columns. The months of January, February, March, and December left out.

Years.	0 to 5 feet.	5 to 10 feet.	10 to 15 feet.	15 to 20 feet.	20 to 25 feet.	25 to 30 feet.	30 to 35 feet.
1861	.....	71	59	85	96	3	.....
1862	.....	32	87	44	50	21	10
1863	56	101	76	11	.....	.....	.....
1864	96	50	79	19	.....	.....	.....
1865	.....	17	96	91	33	7	.....
1866	.....	96	89	87	33	9	.....
1867	.....	79	28	34	57	46	.....
1868	.....	105	64	54	21	.....	.....
1869	.....	.....	38	141	33	32	.....
1870	.....	70	93	37	38.	6	.....
1871	66	64	78	36	.....	.....	.....
1872	8	85	40	78	33	.....	.....
1873	4	96	29	42	70	8	.....
1874	.....	117	92	35	.....	.....	.....
1875	1	46	45	86	43	23	.....
1876	.....	21	75	26	64	52	6
Average	14.4	61.4	66.3	56.6	31.3	12.9	1.0

TABLE D[1].—ROCK ISLAND.

Table, by years, of number of days the river's surface at Rock Island, Ill., was at the heights indicated by the figures at the head of the columns. The months of January, February, March, and December left out.

Years.	0 to 2 feet.	2 to 4 feet.	4 to 6 feet.	6 to 8 feet.	8 to 10 feet.	10 to 12 feet.	12 to 14 feet.	14 to 16 feet.	16 to 18 feet.
1861	20	89	56	9	12	37	13	8	.....
1862	7	94	61	9	21	24	15	13	.....
1863	113	56	34	30	11	.....	.....	.....	.....
1864	177	25	42	.....	.....	.....	.....	.....	.....
1865	.....	79	102	33	14	16	.....	.....	.....
1866	20	119	46	16	17	8	10	8	.....
1867	.....	84	10	18	70	43	15	4	.....
1868	42	84	55	46	17	.....	.....	.....	.....
1869	.....	.....	49	84	65	37	9	.....	.....
1870	.....	42	93	24	47	13	8	8	9
1871	68	79	32	23	22	12	9	.....	.....
1872	36	89	65	38	16	.....	.....	.....	.....
1873	36	83	12	33	35	41	4	.....	.....
1874	11	71	97	59	6	.....	.....	.....	.....
1875	39	69	19	55	41	14	7	.....	.....
1876	.....	92	40	19	32	26	35	.....	.....
Average	35.6	72.2	50.8	30.9	26.6	16.8	7.8	2.6	0.6

From these tables we get the following:

For Saint Louis.

	0 to 5 feet.	0 to 10 feet.	0 to 15 feet.	0 to 20 feet.	0 to 25 feet.	0 to 30 feet.	0 to 35 feet.
Average number of days	14.4	75.8	142.1	198.7	230.0	242.9	243.9+

For Rock Island.

	Between—								
	0 to 2 feet.	0 to 4 feet.	0 to 6 feet.	0 to 8 feet.	0 to 10 feet.	0 to 12 feet.	0 to 14 feet.	0 to 16 feet.	0 to 18 feet.
Average number of days ..	35.6	107.8	158.6	189.5	216.1	232.9	240.7	243.3	243.9+

From these data we make Diagram O, which contains two curves, one for Saint Louis, and one for Rock Island. These curves were constructed with the heights of the river's surface as ordinates, and the number of days it was at or below these heights as abscissas.

Upon this diagram we have drawn a horizontal line 83.8 feet above the zero of the heights, to represent the chord of the Saint Louis bridge, which is 5 feet below the crown of the middle arch. The space between this horizontal line and the Saint Louis curve shows the headway at that bridge.

To determine at what height a bridge at Rock Island would have to be placed to give the same headway, we have taken the height of this horizontal line at intervals of 25 days, and drawn a line, *a b*, through points at the same height above the Rock Island curve. The average height of this line *a b* above the zero (low water), is the height at which a bridge at Rock Island must be built, to give as much headway as is given at Saint Louis. This, by calculation, is found to be about 75.5 feet, which may be seen by a mere inspection of the diagram. That is to say, that a bridge at Rock Island 75.5 feet above low water for half of the time (during high stages) would have from 0 to 7 feet more headway than the bridge at Saint Louis, and the other half (during low stages) the same amount less. Then, in order to receive an average headway as good as Saint Louis, it would have to be placed 75.5 feet above low water, or 59.5 feet above high water.

If the Saint Louis bridge had been built 10 feet higher or lower, a bridge at Rock Island, to give equal average headway, would have to be the same amount higher or lower.

The foregoing discussion and deduction has value only in considering the relative obstruction that high bridges at these places would cause, if boats were compelled to lower their chimneys to pass them.

If boats are built so as to pass under a bridge with 50 feet headway, then bridges at any point need be built but 50 feet above high water.

3. *Quincy tables, &c.*—The gauge observations at this place are for eight years, from January 1, 1869, to December 31, 1876. The rise from low to high water is about 20 feet. The tables are made up with intervals of 2 feet.

The following tables, A, B, C, are constructed for Quincy in the same manner as those for Saint Louis, previously described:

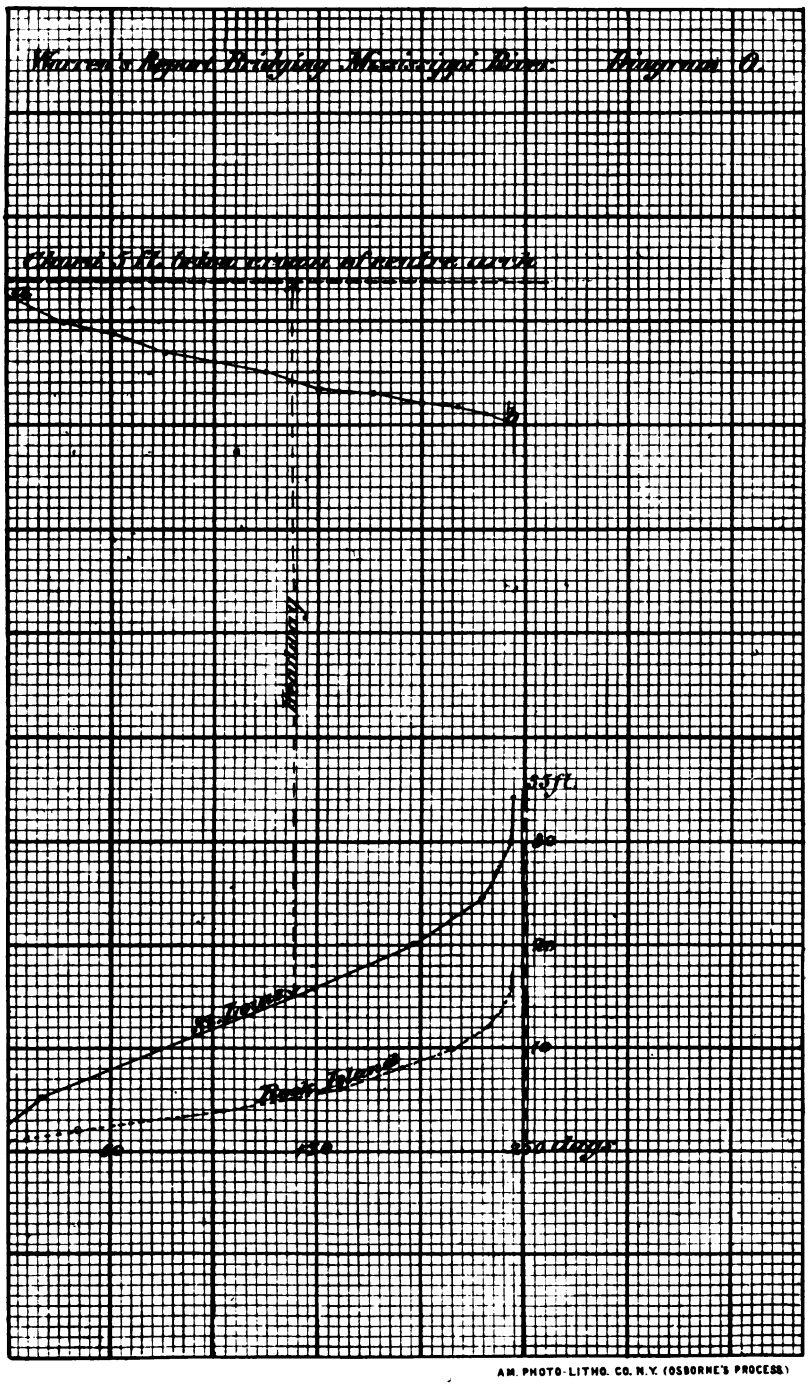


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TABLE A.—QUINCY.

1869.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October	November.	December.	Totals.
0- 2	....	....	....	....	....	....	....	....	....	....	....	....	.....
2- 4	15	13	21	....	....	....	....	....	....	....	....	....	49
4- 6	16	1	10	....	....	....	....	....	....	....	....	15	42
6- 8	....	9	....	2	....	7	....	14	....	....	19	16	67
8-10	....	5	....	4	....	12	....	6	....	....	10	....	37
10-12	....	....	....	24	18	11	4	5	....	7	1	....	70
12-14	....	....	....	....	13	....	14	6	30	24	....	....	87
14-16	....	....	....	....	....	....	8	....	....	....	....	....	8
16-18	....	....	....	....	....	....	5	....	....	....	....	....	5

1870.

0- 2	....	....	....	....	....	....	....	....	....	....	....	2	2
2- 4	3	19	3	....	....	....	6	15	2	....	....	19	67
4- 6	28	9	17	....	....	....	22	16	4	4	21	10	131
6- 8	....	....	2	....	....	11	3	....	10	25	8	....	59
8-10	....	....	3	....	....	17	....	....	14	2	1	....	37
10-12	....	....	3	....	15	2	....	....	....	....	....	....	20
12-14	....	....	3	....	6	....	....	....	....	....	....	....	9
14-16	....	....	....	22	6	....	....	....	....	....	....	....	28
16-18	....	....	....	8	4	....	....	....	....	....	....	....	12

1871.

0- 2	....	....	....	....	....	....	....	....	25	30	7	5	67
2- 4	8	2	....	....	....	....	13	31	5	1	23	26	109
4- 6	14	19	....	....	....	12	18	....	....	....	....	....	63
6- 8	9	2	....	11	....	11	....	....	....	....	....	....	33
8-10	....	1	9	19	2	7	....	....	....	....	....	....	38
10-12	....	4	22	....	19	....	....	....	....	....	....	....	45
12-14	....	....	....	....	10	....	....	....	....	....	....	....	10

1872.

0- 2	....	....	2	....	....	....	....	....	....	4	25	2	33
2- 4	31	27	25	....	....	....	....	14	19	27	5	19	167
4- 6	....	2	3	....	....	....	29	17	11	....	....	10	72
6- 8	....	....	1	15	5	8	2	....	....	....	....	....	31
8-10	....	....	....	15	16	9	....	....	....	....	....	....	40
10-12	....	....	....	....	10	8	....	....	....	....	....	....	18
12-14	....	....	....	....	....	5	....	....	....	....	....	....	5

1873.

0- 2	....	....	....	....	....	....	....	....	14	7	7	14	42
2- 4	21	13	5	....	....	....	....	20	16	24	23	14	136
4- 6	10	13	4	....	....	....	....	10	....	....	....	3	40
6- 8	....	2	6	4	....	....	5	1	....	....	....	....	18
8-10	....	....	7	22	1	....	5	....	....	....	....	....	35
10-12	....	....	9	4	20	7	21	....	....	....	....	....	61
12-14	....	....	....	....	10	23	....	....	....	....	....	....	33

1874.

0- 2	6	3	....	....	....	....	....	....	....	....	....	20	29
2- 4	16	25	3	....	....	....	....	25	18	4	13	11	115
4- 6	9	....	1	4	....	....	2	6	12	27	17	....	78
6- 8	....	....	2	25	11	26	29	....	....	....	....	....	93
8-10	....	....	25	1	20	4	....	....	....	....	....	....	50

TABLE A.—QUINCY—Continued.

1875.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
0- 2	....	4	....	....	....	....	....	....	....	....	6	11	21
2- 4	28	24	11	....	....	....	....	21	5	13	24	17	143
4- 6	3	....	12	....	....	....	....	6	2	11	....	3	37
6- 8	....	....	7	....	....	3	6	2	1	7	....	....	26
8-10	....	....	1	1	6	13	2	2	8	....	....	....	33
10-12	....	....	....	29	14	10	8	....	10	....	....	....	71
12-14	....	....	....	....	11	4	6	....	4	....	....	....	25
14-16	....	....	....	....	....	....	9	....	....	....	....	....	9

1876.

0- 2	....	....	....	....	....	....	....	....	....	....	....	1	1
2- 4	8	9	1	....	....	....	....	....	....	....	....	17	35
4- 6	11	13	6	....	....	....	1	31	3	25	27	13	130
6- 8	3	7	1	....	....	....	4	....	6	6	3	....	30
8-10	3	....	8	2	....	....	4	....	8	....	....	....	25
10-12	4	....	7	9	....	19	7	....	5	....	....	....	51
12-14	2	....	8	2	19	11	6	....	6	....	....	....	54
14-16	....	....	....	7	12	....	9	....	2	....	....	....	30
16-18	....	....	....	10	....	....	....	....	....	....	....	....	10

TABLE B.—QUINCY.

January.

Heights in feet.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 2	....	....	....	....	....	6	....	....	0.7
2- 4	15	3	8	31	21	16	28	8	16.3
4- 6	16	28	14	....	10	9	3	11	11.4
6- 8	....	....	9	....	....	....	....	3	1.5
8-10	....	....	....	....	....	....	....	3	0.4
10-12	....	....	....	....	....	....	....	4	0.5
12-14	....	....	....	....	....	....	....	2	0.2

February.

0- 2	....	....	....	....	....	3	4	....	0.9
2- 4	13	19	2	27	13	25	24	9	16.5
4- 6	1	9	19	2	13	....	....	13	7.1
6- 8	9	....	2	....	2	....	....	7	2.5
8-10	5	....	1	....	....	....	....	....	0.7
10-12	....	....	4	....	....	....	....	....	0.5

March.

0- 2	....	....	....	2	....	....	....	....	0.3
2- 4	21	3	....	25	5	3	11	1	8.6
4- 6	10	17	....	3	4	1	12	6	6.6
6- 8	....	2	....	1	6	2	7	1	2.4
8-10	....	3	9	....	7	25	1	8	6.6
10-12	....	3	22	....	9	....	....	7	5.1
12-14	....	3	....	....	....	....	....	8	1.4

April.

Heights in feet.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 2	.....	.....	.....	.....	.....	.....	.....	.....	.....
2- 4	.....	.....	.....	.....	.....	.....	.....	.....	.....
4- 6	.....	.....	.....	.....	.....	4	.....	.....	0.5
6- 8	2	.....	11	15	4	25	.....	.....	7.1
8-10	4	.....	19	15	22	1	1	2	8.0
10-12	24	.....	.....	.....	4	.....	29	9	8.3
12-14	.....	.....	.....	.....	.....	.....	.....	2	0.3
14-16	.....	22	.....	.....	.....	.....	.....	7	3.6
16-18	.....	8	.....	.....	.....	.....	.....	10	2.3

May.

0- 2	.....	.....	.....	.....	.....	.....	.....	.....	.....
2- 4	.....	.....	.....	.....	.....	.....	.....	.....	.....
4- 6	.....	.....	.....	.....	.....	.....	.....	.....	.....
6- 8	.....	.....	.....	5	.....	11	.....	.....	2.9
8-10	.....	.....	2	16	1	20	6	.....	5.6
10-12	18	15	19	10	20	.....	14	.....	12.0
12-14	13	6	10	.....	10	.....	11	19	8.6
14-16	.....	6	.....	.....	.....	.....	.....	12	2.1
16-18	.....	4	.....	.....	.....	.....	.....	.....	0.5

June.

0- 2	.....	.....	.....	.....	.....	.....	.....	.....	.....
2- 4	.....	.....	.....	.....	.....	.....	.....	.....	.....
4- 6	.....	.....	12	.....	.....	.....	.....	.....	1.5
6- 8	7	11	11	8	.....	26	3	.....	8.2
8-10	12	17	7	9	.....	4	13	.....	7.8
10-12	11	2	.....	8	7	.....	10	19	7.1
12-14	.....	.....	.....	5	23	.....	4	11	5.4

July.

0- 2	.....	.....	.....	.....	.....	.....	.....	.....	.....
2- 4	.....	6	13	.....	.....	.....	.....	.....	2.4
4- 6	.....	22	18	29	.....	2	.....	1	9.0
6- 8	.....	3	.....	2	5	29	6	4	6.1
8-10	.....	.....	.....	.....	5	.....	2	4	1.4
10-12	4	.....	.....	.....	21	.....	8	7	5.0
12-14	14	.....	.....	.....	.....	.....	6	6	3.3
14-16	8	.....	.....	.....	.....	.....	9	9	3.4
16-18	5	.....	.....	.....	.....	.....	.....	.....	0.6

August.

0- 2	.....	.....	.....	.....	.....	.....	.....	.....	.....
2- 4	.....	15	31	14	20	25	21	.....	15.7
4- 6	.....	16	.....	17	10	6	6	31	10.7
6- 8	14	.....	.....	.....	1	.....	2	.....	2.1
8-10	6	.....	.....	.....	.....	.....	2	.....	1.0
10-12	5	.....	.....	.....	.....	.....	.....	.....	0.6
12-14	6	.....	.....	.....	.....	.....	.....	.....	0.7

September.

0- 2	.....	.....	25	.....	14	.....	.....	.....	4.9
2- 4	.....	2	5	19	16	18	5	.....	8.1
4- 6	.....	4	.....	11	.....	12	2	3	4.0
6- 8	.....	10	.....	.....	.....	.....	1	6	2.1
8-10	.....	14	.....	.....	.....	.....	8	8	3.8
10-12	.....	.....	.....	.....	.....	.....	10	5	1.9
12-14	30	.....	.....	.....	.....	.....	4	6	5.0
14-16	.....	.....	.....	.....	.....	.....	.....	2	0.3

October.

Heights in feet.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 2	.....	.....	30	4	7	.....	.....	.....	5.1
2- 4	.....	.....	1	27	24	4	13	.....	8.6
4- 6	.....	4	.....	.....	.....	27	11	25	8.4
6- 8	.....	25	.....	.....	.....	.....	7	6	4.8
8-10	.....	2	.....	.....	.....	.....	.....	.....	0.2
10-12	7	.....	.....	.....	.....	.....	.....	.....	0.9
12-14	24	.....	.....	.....	.....	.....	.....	.....	3.0

November.

0- 2	.....	.....	7	25	7	.....	6	.....	5.6
2- 4	.....	.....	23	5	23	13	24	.....	11.0
4- 6	.....	21	.....	.....	.....	17	.....	27	8.1
6- 8	19	8	.....	.....	.....	.....	.....	3	3.8
8-10	10	1	.....	.....	.....	.....	.....	.....	1.4
10-12	1	.....	.....	.....	.....	.....	.....	.....	0.1

December.

0- 2	.....	2	5	2	14	20	11	1	6.9
2- 4	.....	19	26	19	14	11	17	17	15.4
4- 6	15	10	.....	10	3	.....	3	13	6.8
6- 8	16	.....	.....	.....	.....	.....	.....	.....	2.0

TABLE C.—QUINCY.

Monthly averages for eight years, from 1869 to 1876, inclusive, of number of days the river surface at Quincy, Ill., was at the height indicated by the figures at the head of the columns.

Months.	0 to 2 feet.	2 to 4 feet.	4 to 6 feet.	6 to 8 feet.	8 to 10 feet.	10 to 12 feet.	12 to 14 feet.	14 to 16 feet.	16 to 18 feet.
January	0.7	16.3	11.4	1.5	0.4	0.5	0.2	.....	.....
February	0.9	16.5	7.1	2.5	0.7	0.5	.....	.....	.....
March	0.3	8.6	6.6	2.4	6.6	5.1	1.4	.....	.....
April	.....	.....	0.5	7.1	8.0	8.3	0.3	3.6	2.3
May	.....	.....	.....	2.0	5.6	12.0	8.6	2.1	0.5
June	.....	.....	1.5	8.2	7.8	7.1	5.4	.....	.....
July	.....	2.4	9.0	6.1	1.4	5.0	3.3	3.4	0.6
August	.....	15.7	10.7	2.1	1.0	0.6	0.7	.....	.....
September	4.9	8.1	4.0	2.1	3.8	1.9	5.0	0.3	.....
October	5.1	8.6	8.4	4.8	0.2	0.9	3.0	.....	.....
November	5.6	11.0	8.1	3.8	1.4	0.1	.....	.....	.....
December	6.9	15.4	6.8	2.0	.....	.....	.....	.....	.....
Yearly averages	24.4	102.6	74.1	44.6	36.9	42.0	27.9	9.4	3.4

Comparison of Saint Louis and Quincy with reference to headway.—The river at Quincy is generally free from ice nearly as late in the season as at Saint Louis. In comparing the gauge observations of the two places, we have therefore used them for the whole year.

To show the average number of days in a year that the river is at the different heights on the gauge, the two following tables have been prepared.

Warren's Report Bridging Mississippi River. *Diagram P.*

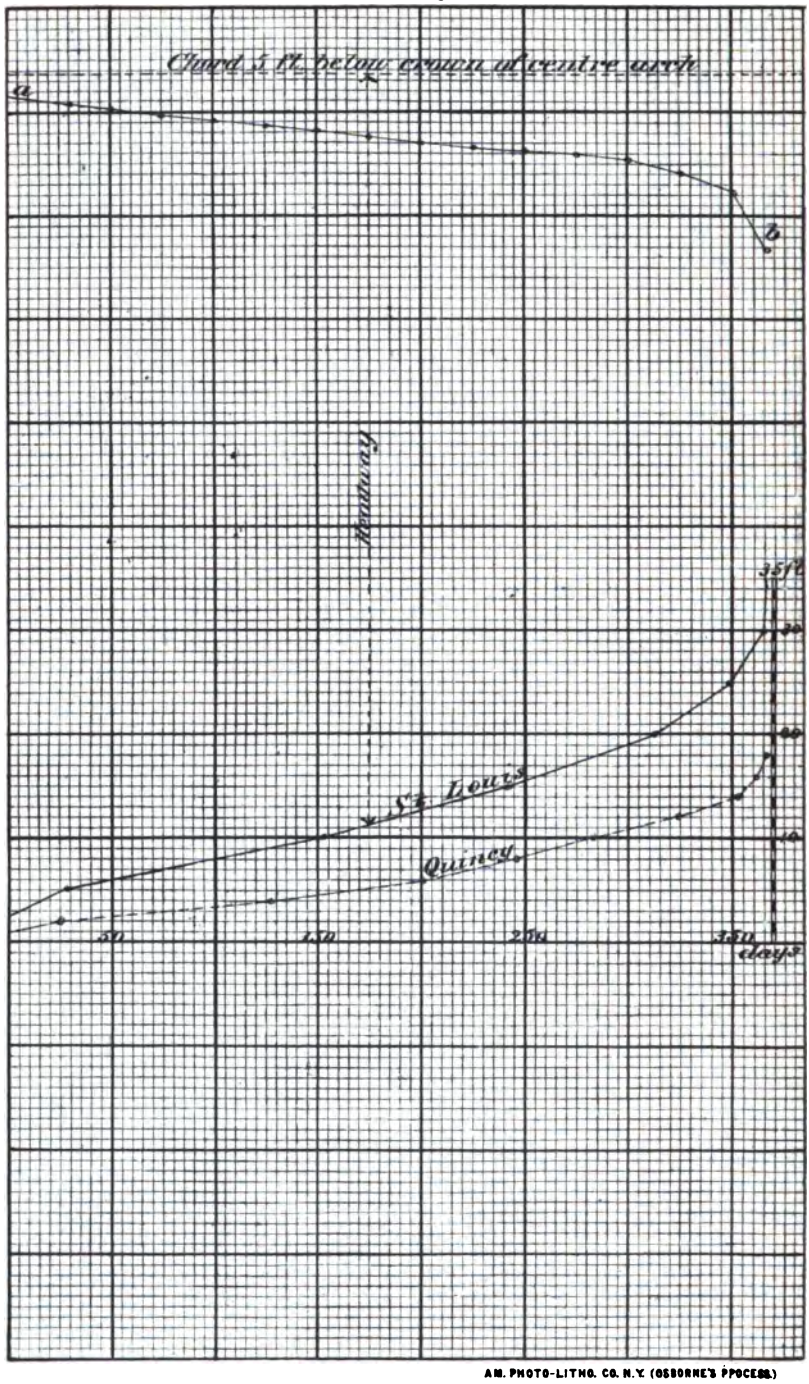

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TABLE D″.—SAINT LOUIS.

Table, by years, of number of days the river's surface at Saint Louis, Mo., was at the heights indicated by the figures at the head of the columns.

Years.	0 to 5 feet.	5 to 10 feet.	10 to 15 feet.	15 to 20 feet.	20 to 25 feet.	25 to 30 feet.	30 to 35 feet.
1869	.....	48	107	145	33	32	.....
1870	.....	176	104	41	38	6	.....
1871	89	104	100	63	9	.....	.....
1872	50	162	43	78	33	.....	.....
1873	7	165	61	54	70	8	.....
1874	32	159	124	50	.....	.....	.....
1875	48	112	53	86	43	23	.....
1876	2	69	123	44	70	52	6
Yearly averages	28.5	124.4	89.4	70.1	37.0	15.1	0.7

TABLE D″.—QUINCY.

Table, by years, of number of days the river-surface at Quincy, Ill., was at the heights indicated by the figures at the head of the columns.

Years.	0 to 2 feet.	2 to 4 feet.	4 to 6 feet.	6 to 8 feet.	8 to 10 feet.	10 to 12 feet.	12 to 14 feet.	14 to 16 feet.	16 to 18 feet.
1869	.....	49	42	67	37	70	87	8	5
1870	2	67	131	59	37	20	9	28	12
1871	67	109	63	33	38	45	10	.....	.....
1872	33	167	72	31	40	18	5	.....	.....
1873	42	136	40	18	35	61	33	.....	.....
1874	29	115	78	93	50	.....	.....	.....	.....
1875	21	143	37	20	33	71	25	9	.....
1876	1	35	130	30	25	51	54	30	10
Yearly averages	24.4	102.6	74.1	44.6	36.9	42.0	27.9	9.4	3.4

From these tables we get the following:

For Saint Louis.

	From—						
	0 to 5 feet.	0 to 10 feet.	0 to 15 feet.	0 to 20 feet.	0 to 25 feet.	0 to 30 feet.	0 to 35 feet.
Number of days	28.5	152.9	242.3	312.4	349.4	364.5	365.2

For Quincy.

	From—								
	0 to 2 feet.	0 to 4 feet.	0 to 6 feet.	0 to 8 feet.	0 to 10 feet.	0 to 12 feet.	0 to 14 feet.	0 to 16 feet.	0 to 18 feet.
Number of days	24.4	127.0	201.1	245.7	282.6	324.6	352.5	361.9	365.3

From the data presented in these tables we construct Diagram P, which contains two curves, one for Saint Louis and one for Quincy, drawn in the same manner as those on Diagram O, previously described.

On this diagram (P) we have drawn a horizontal line, to represent a chord 5 feet below the crown of the center arch of the Saint Louis

bridge; the space between this and the curve of the Saint Louis heights is the headway under the bridge at Saint Louis.

To determine the height of a bridge at Quincy, to give as much average headway as at Saint Louis, we have drawn a line, *a b*, at the same distance above the Quincy curve that the chord of five feet below the crown of the center arch of Saint Louis bridge is above the Saint Louis curve.

The average height of this line *a b* is about 77.2 feet above the zero (low water); therefore a bridge at Quincy, to be as good for navigation as the Saint Louis bridge, would have to be placed 77.2 feet above low water, or 57 feet above high water. This would give more headway when the water was above the average, and less when below, than the Saint Louis bridge.

4. *Dubuque tables, &c.*—The gauge observations at this place are for eight years, from January 1, 1869, to December 31, 1876. The rise from low to extreme high water is about 22 feet; the tables are arranged for intervals of 2 feet rise.

The following tables, A, B, C, for Dubuque, Iowa, are constructed in the same manner as those for Saint Louis, Rock Island, and Quincy, previously described.

TABLE A.—DUBUQUE.

1869.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0- 2												4	4
2- 4													
4- 6								6			2	19	27
6- 8						20	2	18			10	2	52
8-10					2	8	20	7	5		14	6	63
10-12					10	2	9		20	6	4		51
12-14					19				2	8			29
14-16									3	9			12
16-18										8			8

1870.

0- 2								6				8	14
2- 4		3					17	11			9	23	63
4- 6	17	25	20			3	14	14			21		114
6- 8	14		9	1		13			13	13			63
8-10			2	5	1	14			7	18			47
10-12				2	22				10				34
12-14				3	5								8
14-16				4	3								7
16-18				5									5
18-20				10									10
20-22													

1871.

0- 2											1		1
2- 4							6	25	30	31	29	14	135
4- 6	31	23					21	6				17	98
6- 8		2		5		18	4						29
8-10		1	27	7		8							43
10-12		2	4	5	6	4							21
12-14				13	7								20
14-16					10								10
16-18					8								8

1872.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
2- 4	6	11	.....	.....	.....	.....	.....	.....	25	24	30	7	103
4- 6	25	12	29	9	.....	.....	.....	31	5	7	.....	24	143
6- 8	.....	.....	2	11	2	10	30	.....	.....	.....	.....	.....	55
8-10	.....	.....	.....	10	16	13	1	.....	.....	.....	.....	.....	40
10-12	.....	.....	.....	.....	8	7	.....	.....	.....	.....	.....	.....	15
12-14	.....	.....	.....	.....	5	.....	.....	.....	.....	.....	.....	.....	5
14-16	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
16-18	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

1873.

0- 2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2- 4	1	1	.....	.....	.....	.....	.....	4	25	10	9	.....	50
4- 6	30	27	6	.....	.....	.....	.....	24	5	21	21	17	151
6- 8	.....	.....	2	15	.....	.....	5	3	.....	.....	.....	14	39
8-10	.....	.....	23	6	4	2	6	.....	.....	.....	.....	.....	41
10-12	.....	.....	.....	4	12	3	4	.....	.....	.....	.....	.....	23
12-14	.....	.....	.....	5	8	9	12	.....	.....	.....	.....	.....	34
14-16	.....	.....	.....	.....	7	16	4	.....	.....	.....	.....	.....	27
16-18	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

1874.

0- 2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	2
2- 4	.....	.....	.....	.....	.....	.....	.....	19	1	.....	3	8	31
4- 6	31	28	9	.....	.....	.....	1	12	24	9	12	4	130
6- 8	.....	.....	16	23	.....	19	5	.....	5	22	15	17	122
8-10	.....	.....	6	6	6	11	18	.....	.....	.....	.....	.....	47
10-12	.....	.....	.....	1	23	.....	7	.....	.....	.....	.....	.....	31
12-14	.....	.....	.....	.....	2	.....	.....	.....	.....	.....	.....	.....	2
14-16	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
16-18	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
18-20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

1875.

0- 2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	6	.....	6
2- 4	.....	2	.....	.....	.....	.....	1	31	3	13	7	6	63
4- 6	31	26	26	.....	.....	.....	13	.....	4	16	17	23	156
6- 8	.....	.....	2	.....	.....	.....	6	.....	9	2	.....	2	29
8-10	.....	.....	3	8	.....	8	6	.....	14	.....	.....	.....	31
10-12	.....	.....	.....	9	5	22	5	.....	.....	.....	.....	.....	41
12-14	.....	.....	.....	6	21	.....	.....	.....	.....	.....	.....	.....	27
14-16	.....	.....	.....	3	5	.....	.....	.....	.....	.....	.....	.....	8
16-18	.....	.....	.....	4	.....	.....	.....	.....	.....	.....	.....	.....	4

1876.

0- 2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2- 4	1	13	.....	.....	.....	.....	.....	.....	.....	.....	1	5	20
4- 6	20	16	11	.....	.....	.....	12	30	8	31	29	26	183
6- 8	10	.....	7	5	.....	.....	7	.....	22	.....	.....	.....	51
8-10	.....	.....	5	3	.....	5	4	1	.....	.....	.....	.....	18
10-12	.....	.....	8	4	.....	14	7	.....	.....	.....	.....	.....	33
12-14	.....	.....	.....	1	8	6	1	.....	.....	.....	.....	.....	16
14-16	.....	.....	.....	17	17	5	.....	.....	.....	.....	.....	.....	39
16-18	.....	.....	.....	.....	6	.....	.....	.....	.....	.....	.....	.....	6
18-20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE B.—DUBUQUE.

January.

Heights in feet.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 2									
2- 4				6	1			1	1.0
4- 6			31	25	30	31	31	29	24.0
6- 8		17						10	4.0
8-10		14							2.0

February.

0- 2									
2- 4				11	1		2	13	3.8
4- 6		3	23	18	27	28	26	16	20.1
6- 8		25	2						3.9
8-10			1						0.1
10-12			2						0.3

March.

0- 2									
2- 4									
4- 6				29	6	9	26	11	11.6
6- 8		20		2	2	16	2	7	7.0
8-10		9	27		23	6	3	5	10.4
10-12		2	4					8	2.0

April.

0- 2									
2- 4									
4- 6				9					1.1
6- 8			5	11	15	23		5	8.4
8-10		1	7	10	6	6	8	3	5.8
10-12	8	5	5		4	1	9	4	4.0
12-14	8	2	13		5		6	1	3.8
14-16	3	3					3	17	3.3
16-18		4					4		1.1
18-20		5							0.7
20-22		10							1.4

May.

0- 2									
2- 4									
4- 6									
6- 8				2					0.2
8-10	2			16	4	6			3.5
10-12	10	1	6	8	12	23	5		8.1
12-14	19	22	7	5	8	2	21	8	11.5
14-16		5	10		7		5	17	5.5
16-18		3	8					6	2.1

June.

0- 2									
2- 4									
4- 6									
6- 8	20	3	18	10		19			8.7
8-10	8	13	8	13	2	11	8	5	8.5
10-12	2	14	4	7	3		22	14	8.3
12-14					9			6	1.9
14-16					16			5	2.6

July.

Height in feet.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 2	.....	.....	.....	.....	.....	.....	.....	.....	.....
2- 4	.....	.....	6	.....	.....	.....	1	.....	0.9
4- 6	.....	17	21	.....	.....	1	13	12	8.0
6- 8	2	14	4	30	5	5	6	7	9.1
8-10	20	.....	.....	1	6	18	6	4	6.9
10-12	9	.....	.....	.....	4	7	5	7	4.0
12-14	.....	.....	.....	.....	12	.....	.....	1	1.6
14-16	.....	.....	.....	.....	4	.....	.....	.....	0.5

August.

0- 2	.....	.....	.....	.....	.....	.....	.....	.....	.....
2- 4	.....	6	25	.....	4	19	31	.....	10.6
4- 6	6	11	6	31	24	12	.....	30	15.0
6- 8	18	14	.....	.....	3	.....	.....	.....	4.4
8-10	7	.....	.....	.....	.....	.....	.....	1	1.0

September.

0- 2	.....	.....	.....	.....	.....	.....	.....	.....	.....
2- 4	.....	.....	30	25	25	1	3	.....	10.5
4- 6	.....	.....	.....	5	5	24	4	8	5.7
6- 8	.....	.....	.....	.....	.....	5	9	22	4.5
8-10	5	13	.....	.....	.....	.....	14	.....	4.0
10-12	20	7	.....	.....	.....	.....	.....	.....	3.4
12-14	2	10	.....	.....	.....	.....	.....	.....	1.5
14-16	3	.....	.....	.....	.....	.....	.....	.....	0.4

October.

0- 2	.....	.....	.....	.....	.....	.....	.....	.....	.....
2- 4	.....	.....	31	24	10	.....	13	.....	9.8
4- 6	.....	.....	.....	7	21	9	16	31	10.5
6- 8	.....	.....	.....	.....	.....	22	2	.....	3.0
8-10	.....	13	.....	.....	.....	.....	.....	.....	1.6
10-12	6	18	.....	.....	.....	.....	.....	.....	3.0
12-14	2	.....	.....	.....	.....	.....	.....	.....	1.0
14-16	9	.....	.....	.....	.....	.....	.....	.....	1.1
16-18	8	.....	.....	.....	.....	.....	.....	.....	1.0

November.

0- 2	.....	.....	1	.....	.....	.....	6	.....	0.9
2- 4	.....	.....	29	30	9	3	7	1	9.8
4- 6	2	9	.....	.....	21	12	17	29	11.2
6- 8	10	21	.....	.....	.....	15	.....	.....	5.8
8-10	14	.....	.....	.....	.....	.....	.....	.....	1.8
10-12	4	.....	.....	.....	.....	.....	.....	.....	0.5

December.

0- 2	.....	.....	.....	.....	.....	2	.....	.....	0.2
2- 4	4	8	14	7	.....	8	6	5	6.5
4- 6	19	23	17	24	17	4	23	26	19.1
6- 8	2	.....	.....	.....	14	17	2	.....	4.4
8-10	6	.....	.....	.....	.....	.....	.....	.....	0.8

TABLE C.—DUBUQUE.

Monthly averages for eight years, from 1869 to 1876, inclusive, of number of days the river surface at Dubuque, Iowa, was at the height indicated by the figures at the head of the columns.

Months.	0 to 2 feet.	2 to 4 feet.	4 to 6 feet.	6 to 8 feet.	8 to 10 feet.	10 to 12 feet.	12 to 14 feet.	14 to 16 feet.	16 to 18 feet.	18 to 20 feet.	20 to 22 feet.
January	.....	1.0	24.0	4.0	2.0	.....	.....	.....	.....	.....	.....
February	.....	3.8	20.1	3.9	0.1	0.3	.....	.....	.....	.....	.....
March	.....	.....	11.6	7.0	10.4	2.0	.....	.....	.....	.....	.....
April	.....	.....	1.0	8.4	5.2	4.7	4.6	3.5	1.0	0.6	1.2
May	.....	.....	.....	0.2	3.5	8.1	11.5	5.5	2.1	.....	.....
June	.....	.....	.....	8.7	8.5	8.2	1.9	2.6	.....	.....	.....
July	.....	0.9	8.0	9.1	6.9	4.0	1.6	0.5	.....	.....	.....
August	.....	10.6	15.0	4.4	1.0	.....	.....	.....	.....	.....	.....
September	.....	10.5	5.7	4.5	4.0	3.4	1.5	0.4	.....	.....	.....
October	.....	9.8	10.5	3.0	1.6	3.0	1.0	1.1	1.0	.....	.....
November	0.9	9.8	11.2	5.8	1.8	0.5	.....	.....	.....	.....	.....
December	0.2	6.5	19.1	4.4	0.8	.....	.....	.....	.....	.....	.....
Yearly averages	1.1	52.9	126.2	63.4	45.8	34.2	22.1	13.6	4.1	0.6	1.2

For the months of January, February, March, and April the averages are for seven years, no gauge being kept for these months in 1869.

Comparison of Saint Louis and Dubuque with reference to headway.—The river at Dubuque is generally closed by ice from December 1 to April 1; we have therefore left out this period in the tables that follow.

These tables show the average number of days in the eight months, from April 1 to December 1, that river's surface was at the different heights noted at the head of the columns.

TABLE D'''.—SAINT LOUIS.

Table, by years, of numbers of days the river's surface at Saint Louis, Mo., was at the heights indicated by the figures at the heads of the columns.

[The months of January, February, March, and December left out.]

Years.	0 to 5 feet.	5 to 10 feet.	10 to 15 feet.	15 to 20 feet.	20 to 25 feet.	25 to 30 feet.	30 to 35 feet.
1869	.....	.....	38	141	33	32	.....
1870	.....	70	93	37	38	6	.....
1871	66	64	78	36	.....	.....	.....
1872	8	85	40	78	33	.....	.....
1873	4	98	22	42	70	8	.....
1874	.....	117	92	35	.....	.....	.....
1875	1	46	45	86	43	23	.....
1876	.....	21	75	26	64	52	6
Average number of days	11.3	71.6	63.6	48.6	35.4	12.7	0.8

The year 1869 is not included in getting the average.

Warren's Report Bridging Mississippi River. *Diagram Q.*

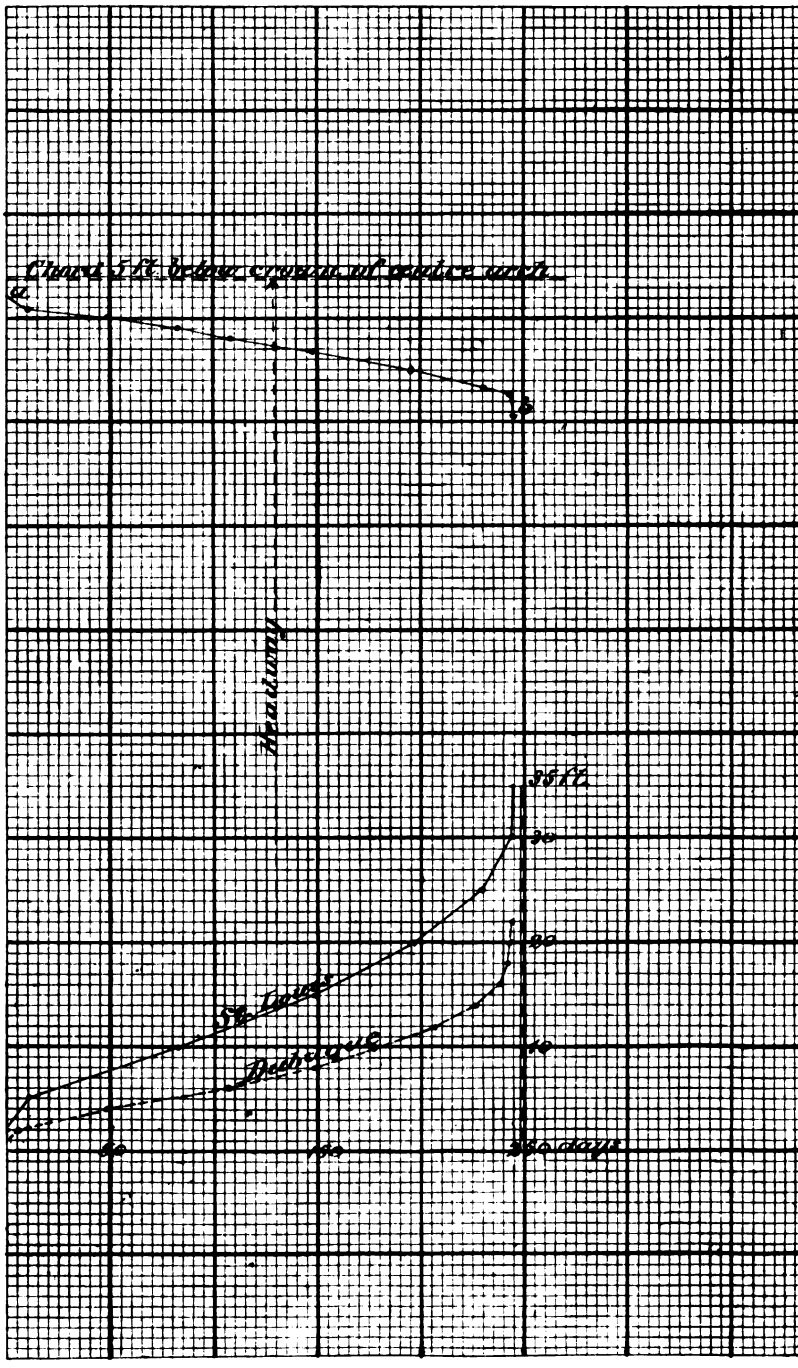

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TABLE D'''.—DUBUQUE.

Table, by years, of number of days the river's surface at Dubuque, Iowa, was at the heights indicated by the figures at the heads of the columns.

[The months of January, February, March, and December left out.]

Years.	0 to 2 feet.	2 to 4 feet.	4 to 6 feet.	6 to 8 feet.	8 to 10 feet.	10 to 12 feet.	12 to 14 feet.	14 to 16 feet.	16 to 18 feet.	18 to 20 feet.	20 to 22 feet.
1869	.....	8	50	57	51	29	12	8	.....	.....	.....
1870	.....	6	37	52	40	45	34	8	7	5	10
1871	1	121	27	27	15	15	20	10	8	.....	.....
1872	.....	79	52	53	40	15	5	.....	.....	.....	.....
1873	.....	48	71	23	18	23	34	27	.....	.....	.....
1874	.....	23	58	89	41	31	2	.....	.....	.....	.....
1875	6	55	50	17	36	41	27	8	4	.....	.....
1876	.....	1	110	34	13	25	16	39	6	.....	.....
Average	1.0	47.6	57.8	42.1	29.0	27.9	19.7	13.1	3.6	0.7	1.4

The average is for seven years, the observations not commencing until May 1, 1869; that year is not included.

From these tables we get the following:

For Saint Louis.

	From 0 to—						
	5 feet.	10 feet.	15 feet.	20 feet.	25 feet.	30 feet.	35 feet.
Number of days	11.3	82.9	146.5	195.1	230.5	243.2	244

For Dubuque.

	From 0 to—										
	2 feet.	4 feet.	6 feet.	8 feet.	10 feet.	12 feet.	14 feet.	16 feet.	18 feet.	20 feet.	22 feet.
No. of days	1.0	48.6	106.4	148.5	177.5	205.4	225.1	238.2	241.8	242.5	244

From the data contained in these tables, we construct Diagram Q, which contains two curves, one for Saint Louis and one for Dubuque. These are constructed in the same manner as those for Saint Louis and Rock Island, &c. The averages are for but 7 years, and for eight months in the year, leaving out the winter months of December, January, February, and March.

The line *a b* on this diagram is drawn at the same height above the Dubuque curve as the horizontal line, representing a chord 5 feet below the crown of the center arch of the Saint Louis bridge.

The average height of this line is 77.5 feet above the zero (low water).

This, then, is the height of a bridge at this place, that would give as good average headway as the Saint Louis bridge.

The rise from low to high water is 22 feet; the bridge would therefore have to be 55.5 feet above high water.

5. *Other places on the Mississippi where gauge-observations have been made.*—These are enumerated in the first part of this chapter. At none of these is the period observed greater than three years and only for

seasons of navigation. The deductions from a mean of these would not have the weight of those already discussed. We have thought it sufficient, therefore, to give diagrams of the gauge-observations themselves at those places, each by itself (see diagrams S, T, U, V), and with them Diagram R of the gauge-readings for the three corresponding years and seasons at Rock Island for comparison.

The examination of Diagram K has shown that there is much similarity between the means of eight years at Rock Island and Dubuque, omitting the winter months, and this similarity to Rock Island is shown as far as they can affect this question by the diagrams at Clinton, Prairie du Chien, Winona, and Saint Paul. It seems fair to conclude that the corresponding means, if we had the whole eight years' observations at these places, would present a result in regard to required headway not materially different from that at Quincy, Rock Island, and Dubuque. In other words, the bridges along the Upper Mississippi, to provide the same average headway as the present bridge at Saint Louis, should be about 77 feet above low water. This remark may be taken to include Burlington and other places where we have no gauge-observations, until we get so far below the Louisiana bridge as to encounter the effect of back water from the Missouri River.

This point is not yet determined, and it would be only a safe precaution to cause all continuous bridges below the Louisiana bridge to give a clear headway at least 55 feet above high water. The range of the Upper Mississippi between low and high water from the Louisiana bridge upward, as far as is known, nowhere exceeds that at Dubuque—namely, 22 feet.

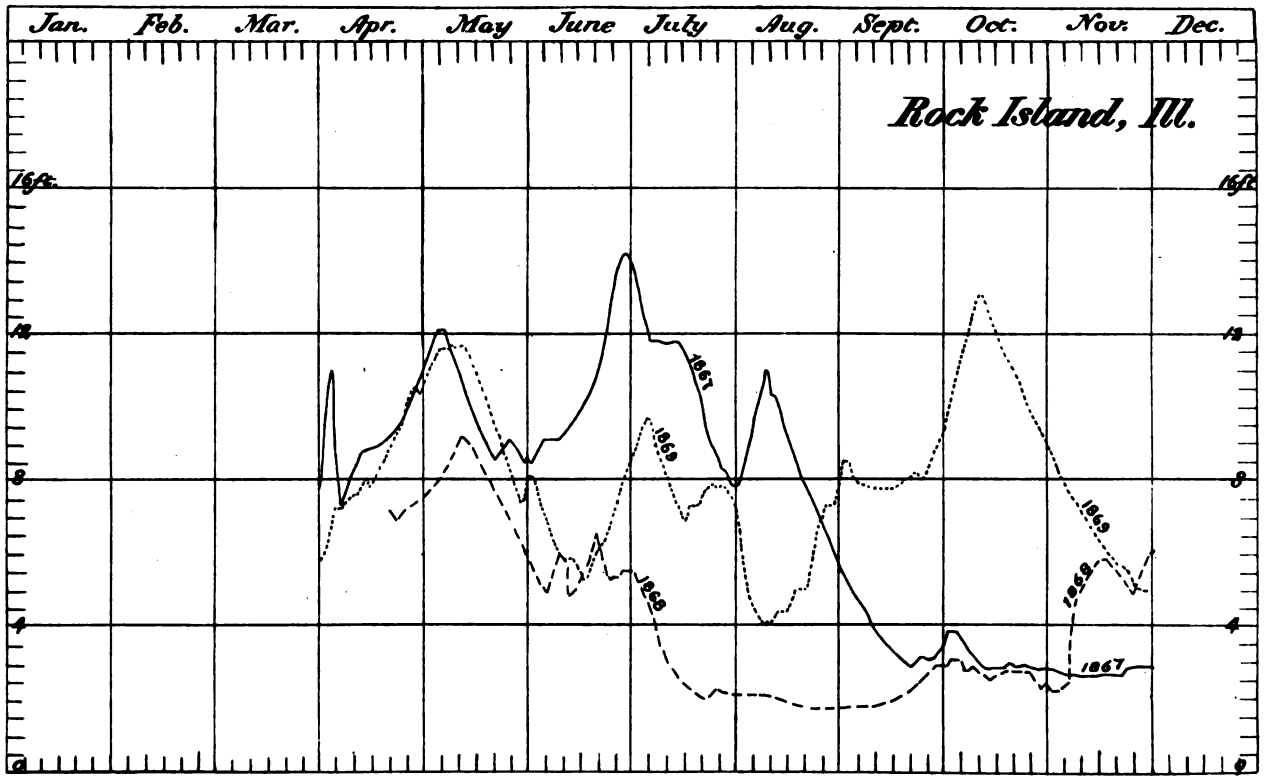
An exception to the above general remarks as to requirements of headway above low water may be made to the broad portion of the valley from a point about ten miles below La Crosse, and extending up to the head of Lake Pepin, where a height 74 or 75 feet above low water would give the equivalent headway to the Saint Louis bridge.

As has been said before, this treatment of the question of relative practicable headway is made under the idea that vessels having different heights of chimneys and pilot-houses are to navigate the river, and then the required heights above low water are intended to make them all equal in their effect, so that a vessel that could pass under one could generally pass under all. But if the boats are all reduced to one fixed height of pilot-house or chimney, then the only requirement is that the bridges shall all be an equal height above high water.

General rule for equating headway at places having different ranges from high to low water.—An examination of the preceding discussion of relative headway at Saint Louis, Quincy, Rock Island, and Dubuque, where the observations extend over long periods (and which leaves out extraordinary floods), shows the probable existence of a law, that the equivalent headway in all cases will be secured by establishing a fixed height, not above low water or high water, but above the midway height.

Place.	Range from low to high water.	Half range.	Height above high water.	Height above low water.	Height above mid range.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Saint Louis	35	17.5	50.0	8.5	67.5
Quincy	20	10.0	57.2	77.2	67.2
Rock Island	16	8.0	59.5	75.5	67.5
Dubuque	22	11.0	55 5	77.5	66.5

Warren's Report Bridging Mississippi River. *Diagram R.*



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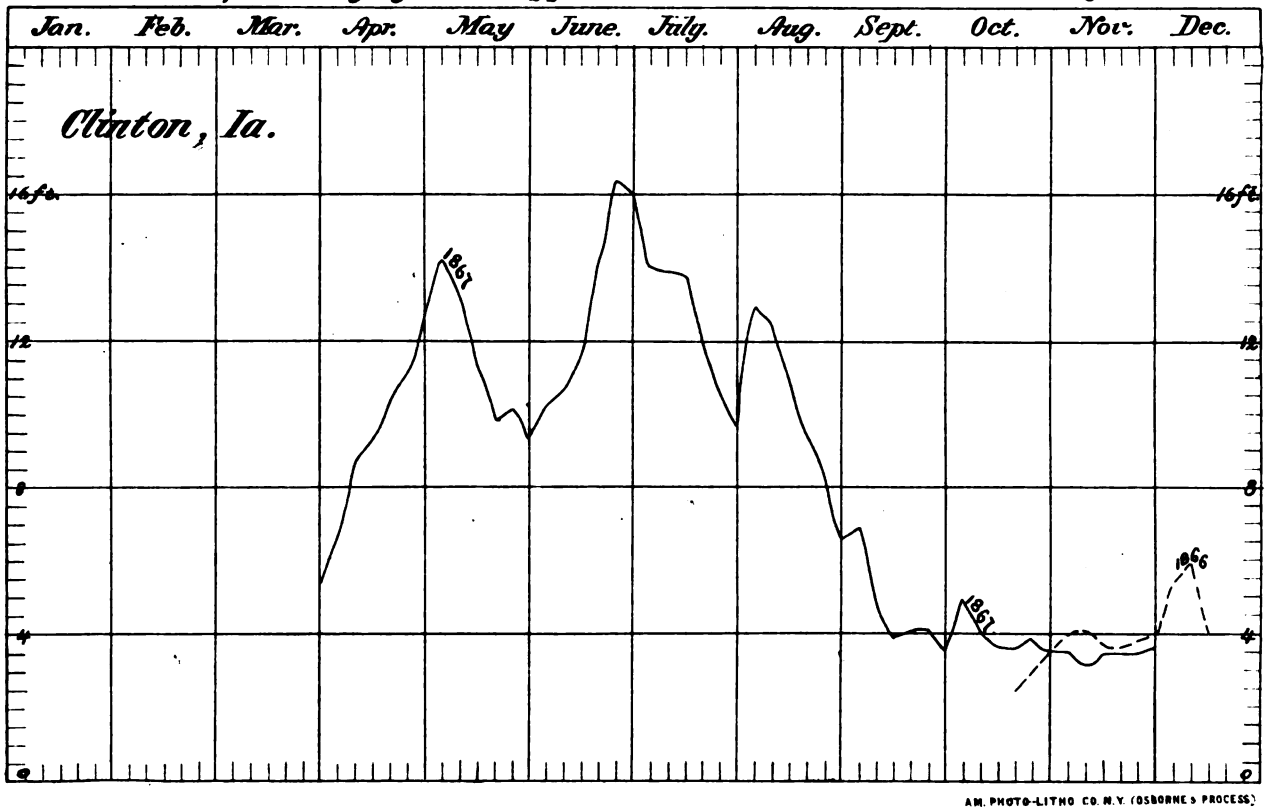
Warren's Report Bridging Mississippi River. *Diagram S.*



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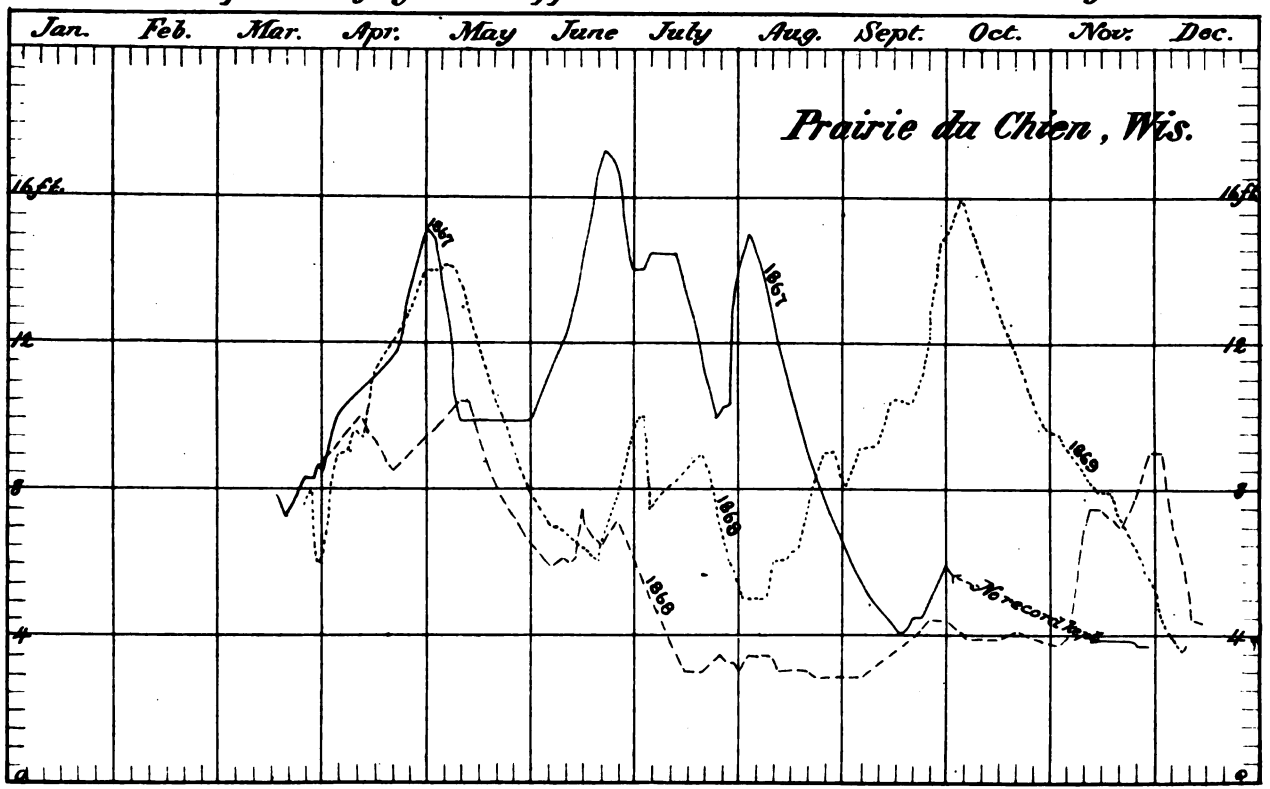
Warren's Report Bridging Mississippi River. Diagram T.



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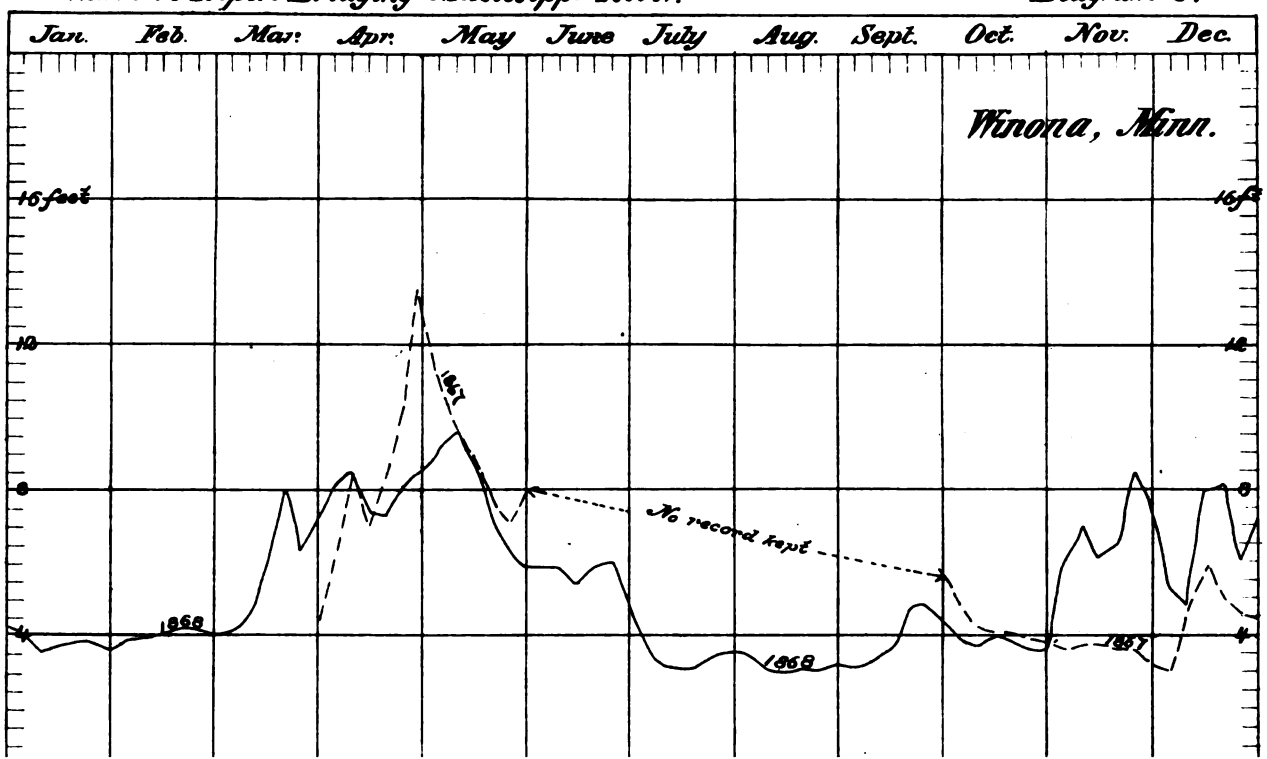
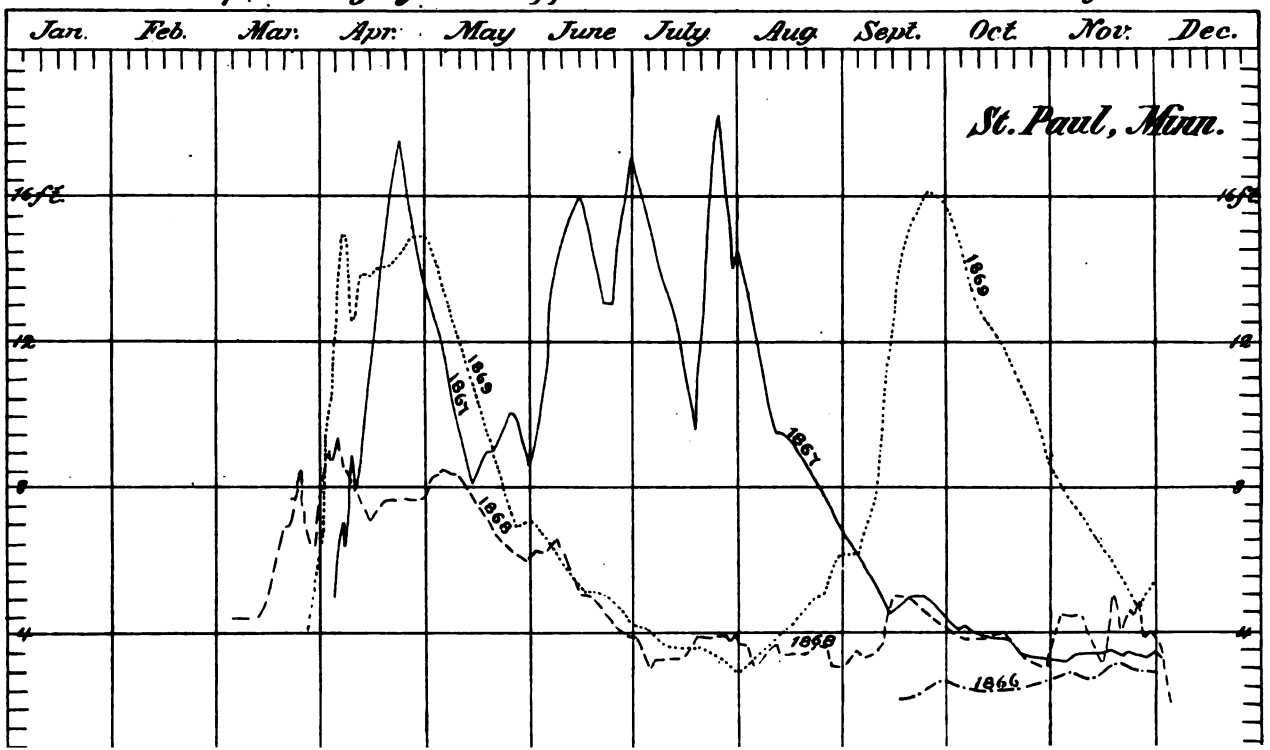
Warren's Report Bridging Mississippi River. Diagram U.



Warren's Report Bridging Mississippi River. Diagram V.



The following table gives the range from low to high water as determined by us on the Upper Mississippi, to which we have added the like ranges on the Lower Mississippi, the Ohio, and Missouri, as for as we have been able to ascertain them.

Table of ranges from low to high water on the Mississippi, Ohio, and Missouri Rivers.

Place.	Range from low to high water.	Date.		Authority.	Remarks.
		High water.	Low water.		
	Feet.				
Saint Paul, Minn	22	1859	1864	Warren's bridge survey	
Hastings, Minn	22	1859	1864	....do	
Prescott, Wis	21	1859	1864	....do	
Lake Pepin	17	.....	1864	....do	
Alma, Wis	18	*1859	1864	....do	
Winona, Minn	17	.....	1864	....do	
La Crosse, Wis	16	.....	1864	....do	
Bad Axe, Wis	16.4	.....	1864	....do	
Prairie du Chien, Wis	22	.....	1864	....do	
Dubuque, Iowa	22	.....	1864	Railroad Bridge Company	
Clinton, Iowa	18.5	1859	1864	Warren's bridge surveys	
Rock Island, Ill	16.6	.....	1864	....do	
Burlington, Iowa	20	1851	1864	Railroad Bridge Company	
Head of Des Moines Rapids	14	.....	1853	Lieut. G. K. Warren	
Foot of Des Moines Rapids	22	.....	1853	....do	
Quincy, Ill	20.2	1851	1864	Railroad Bridge Company	
Hannibal, Mo	22	1851	1864	....do	
Louisiana, Mo	20.5	.....	1864	....do	
Mouth of Illinois	39	1844	1864	R. A. Brown, civil engineer, assistant to Colonel Macomb.	Extraordinary floods.
Alton, Ill	39.5	1844	1864	R. E. McMath, assistant to General Simpson.	Do.
Saint Louis, Mo	41.4	1844	1864	City officers	Extraordinary flood; ordinary flood 35 ft.
Fountain Bluff, Ill	44	.....	1864	Warren's bridge surveys	
Commerce, Mo	48	.....	.....	....do	
Cairo, Ill	51	1858	1855	Humphreys and Abbot	

*June 8.

Mississippi River below Cairo.

Cairo, Ill	52.2	1862	1855	Humphreys and Abbot; changes by General Abbot (Annual Report Chief of Engineers, 1875, p. 568.)	Extraordinary floods
Columbus, Ky	47	1858	1855	....do	Do.
Memphis, Tenn	40.5	1862	1855	....do	Do.
Napoleon, Ark	52.0	1862	1855	....do	Do.
Vicksburg, Miss	51.2	1862	1855	....do	Do.
Natchez, Miss	53.1	1862	1855	....do	Do.
Red River Landing, La	44.3	1851	1851	....do	Do.
Baton Rouge, La	32.4	1862	1851	....do	Do.
Donaldsonville, La	24.3	1851	1851	....do	Do.
Carrollton, La	15.4	1874	1851	....do	Do.
Fort Saint Philip, La	4.5	1851	1851	....do	Do.
Head of Passes, La	2.3	1851	1851	....do	Do.

Ohio River.

Pittsburgh, Pa	35.6	1832	.....	Report of Board of Engineers on Ohio bridges, in Annual Report Chief of Engineers for 1871, p. 398.	
Steubenville, Ohio	45	1832	.....	....do	
Wheeling, W. Va	43.5	1832	.....	....do	
Bellaire, Ohio	50	1832	.....	....do	
Parkersburg, W. Va	50	1832	.....	....do	
Letart's Falls	58	1832	.....	....do	
Gallipolis, Ohio	54	1832	.....	....do	
Cincinnati, Ohio	62.5	1832	.....	....do	
Louisville, Ky	44.5	1832	.....	....do	
New Albany, Ind	63.6	1832	.....	....do	
Evansville, Ind	46	1832	.....	....do	
Paducah, Ky	52.25	1832	.....	....do	

Table of ranges from low high to water, &c.—Continued.

*Missouri River.**

Place.	Range from low to high water.	Date.		Authority.	Remarks.
		High water.	Low water.		
	Feet.				
Omaha, Nebr	19	.....	.....	.....	
Nebraska City, Nebr	22	1844	.....	.....	
Saint Joseph, Mo	22	1844	.....	E. D. Mason, chief engineer	
Atchison, Kans	25	1844	.....	Gardner, Hayden's Survey of Territories.	
Leavenworth, Kans	22	1867	.....	Corps of Engineers, United States Army.	
Leavenworth, Kans	25	1844	1867	Gannett, Hayden's Survey of Territories.	
Kansas City, Kans	37	1844	.....	.....	
Booneville, Mo	23.6	1844	1872	William Sooy Smith, civil engineer.	
Saint Charles, Mo	40	.....	.....	C. Shaler Smith, civil engineer	

*High water of 1844 was extraordinary on the Missouri, some 15 feet above ordinary floods at Kansas City and about 6 feet above at Saint Charles.

CHAPTER IV.

DESCRIPTION OF BRIDGES ON THE MISSISSIPPI RIVER FROM SAINT PAUL, MINN., TO SAINT LOUIS, MO.

Introductory remarks—Outline of treatment of each bridge—SAINT PAUL RAILWAY DRAW-BRIDGE—SAINT PAUL ELEVATED HIGHWAY BRIDGE—HASTINGS RAILWAY DRAW-BRIDGE—WINONA RAILWAY DRAW-BRIDGE—LA CROSSE RAILWAY DRAW-BRIDGE—PRAIRIE DU CHIEN PONTON RAILWAY DRAW-BRIDGE—DUBUQUE RAILWAY DRAW-BRIDGE—CLINTON RAILWAY DRAW-BRIDGE—ROCK ISLAND RAILWAY AND HIGHWAY DRAW-BRIDGE—BURLINGTON RAILWAY DRAW-BRIDGE—KEOKUK RAILWAY AND HIGHWAY DRAW-BRIDGE—QUINCY RAILWAY DRAW-BRIDGE—HANNIBAL RAILWAY AND HIGHWAY BRIDGE—LOUISIANA RAILWAY DRAW-BRIDGE—SAINT LOUIS ELEVATED RAILWAY AND HIGHWAY BRIDGES—BRIDGES ON THE MISSISSIPPI BETWEEN SAINT PAUL AND SAINT LOUIS AUTHORIZED BUT NOT BUILT.

Introductory remarks.—When this report was ordered by Congress in 1866 there were but two of these bridges, as they now stand, in existence—the elevated highway bridge at Saint Paul, and the low railway draw-bridge at Clinton. The former bridge has practically never been any obstruction to navigation. The Clinton draw-bridge was without authorization by Congress, but was declared a post-route in February, 1867. It is the bridge with the narrowest draw-openings authorized by Congress, and has but one draw-opening available. The old draw-bridge at Rock Island was then standing, but Congress had never authorized it, and in 1866 initiated legislation for its removal, which finally took place in 1872.

This bridge was undoubtedly the worst artificial obstruction to navigation that has been built on the Mississippi. With the exception of a very complete report upon the old Rock Island draw-bridge by the officers of Topographical Engineers, Humphreys, Meade, and Franklin, made n 1859, there was no published official report of any of the bridges on

the Mississippi, or of the best kind of bridge within practicable limits to avoid obstructing its navigation. This chapter, therefore, supplies a want in the consideration of the main question of great value. The number of draw-bridges now built, and the variety of circumstances under which they were constructed, seem to be sufficient to apply the test of experience and exact observed conditions. The observations made run over periods of low and medium high-water stages at many places, and are of a kind that requires time in order to obtain opportunity to observe them. I have concluded the report upon each bridge with remarks upon its effects on navigation, and with opinions from the report of the board of engineers upon sheer-booms, of which Colonel Macomb was president, I being a member, and to which the maps accompanying this chapter were submitted, recommending certain modifications for the benefit of rafts. I have also made suggestions for changes to facilitate the passage of steamboats; but, to quote the language of the board just referred to:

> The plans and locations of most of the bridges are such as to make any complete measures for the safety of navigation impossible. (Annual Report Chief of Engineers for 1877, p. 827.)

Outline of the treatment of each bridge.—This order is followed as closely in all cases as the differences which are presented will admit. It is necessarily departed from somewhat in giving an account of the Rock Island bridge, which was designed by me.

NAME OF BRIDGE.

When built and opened.
Authority. To whom granted.

DESCRIPTION OF RIVER AND VALLEY AT THE LOCALITY.

Widths at low and high water; terraces; bluffs; rise from low to high water; slopes; bed of sand or rock; peculiarities.

SURVEYS MADE.

When; to what extent; for what purpose.

DESCRIPTION OF BRIDGE.

Approaches and arrangement of spans; grades.
Substructure; foundations; dimensions of piers; pivot pier and guard.
Superstructure; kind of; by whom built; management of draw; management of bridge; accessory works.

INFLUENCE UPON NAVIGATION.

Upon steamboats; upon rafts; directions of current; velocity; accidents.

ALTERATIONS TO LESSEN OBSTRUCTIONS.

To rafts; to steamboats.

HIGH BRIDGE.

Approaches; height above low water.

SAINT PAUL RAILWAY DRAW-BRIDGE.

(Opened for travel in 1869.)

The only authority for building this bridge is in the act of the legislature of the Territory of Minnesota, approved February 20, 1855, incorporating the Southern Minnesota and Root River Valley Railroad Company. Section 11 of that act contains the following:

> For the purpose of constructing and using said railroad the said corporation is authorized to construct their said railroad and the necessary bridges across and over public highways and navigable streams: *Provided*, That it be so done as not to obstruct or impede the navigation of any navigable stream. * * *

By act of the legislature of Minnesota, approved May 22, 1857, the above-named company was authorized to build a railroad from Saint Paul and from Saint Anthony to a junction at Shakopee, thence up Minnesota River, with the same powers, &c., granted to the company in act of corporation. By act of legislature of Minnesota, approved March 4, 1864, the above-named corporation was divided into two corporations, "The Southern Minnesota Railroad Company," and "The Minnesota Valley Railroad Company." By act of legislature approved March 1, 1870, the latter name was changed to Saint Paul and Sioux City Railroad Company. This company built the bridge and operate it. The Milwaukee and Saint Paul Railway Company run their trains over it.

DESCRIPTION OF THE RIVER AND VALLEY AT THE LOCALITY.

(See Diagram 4.)

The width of the low water river at the site of the bridge is about 1,300 feet; within 1,000 feet above this width decreases to 700 feet. The high water width here is about 3,000 feet. The left bank is bounded by a low rock terrace about 50 feet high; on the right side of the valley the bluff rises to the height of 125 to 150 feet. This bridge is but 2 miles above the highway bridge at Saint Paul. The rise from low to high water is about 22 feet. The current is gentle at low water; at high water it is probably as much as 6 or 7 miles per hour. The slope of the water's surface is about 1 foot per mile.

The bed of the low water river is composed of sand; its depth is not known to me.

SURVEYS.

In September, 1866, a survey was made of this section from mouth of Minnesota River, 4 miles above to 9 miles below. This survey determined the lines of the low banks, of the overflowed bottom lands, and of the bluffs, the slope of the water's surface, and, by soundings, the depth of the river. The survey was made with a view to obtain a knowledge of the river preparatory to devising a plan for its improvement. The piers of the bridge had been commenced at that time and careful soundings were made about them. In October, 1868, a special survey was made at this bridge, including soundings and current observations. In September, 1876, an examination was made, but no current observations were taken, they having been made by Colonel Farquhar, in July preceding.

DESCRIPTION OF BRIDGE.

(See Diagram 5.)

Approaches.—Commencing at the bluff on the right side of the valley the bridge approach crosses a lagoon or lake called Pickerel Lake on a

curve of about 1,340 feet radius, and about 1,100 feet long, then on a straight line to the abutment on the left bank. The left bank approach is on a curve of about 1,145 feet radius. The approach on the right bank is of trestling resting upon piles sawed off near the surface of the ground and in the lake just above low water. The approach on the left bank is on an embankment.

Arrangement of spans.—The first span, commencing on the right bank, is 150 feet from centers; the next two (pivot-draw), 270 feet from end to end, with clear openings of 114 feet; then six spans, 150 feet each; in all 1,320 feet from end to end of bridge.

Substructure.—The piers of this bridge are, with the exception of the pivot, 22 feet long, and 7 feet wide on top, with a batter of ½ inch to the foot. All have triangular ends, except the one standing on the left bank. The pier to the right of the pivot, the pivot, and two piers to the left, rest upon piles cut off below low water. The others rest upon the bed of the river, and are protected by riprap. The pivot-pier is circular in plan, 30 feet in diameter. All of the piers are of masonry. The stone for them came from the bluffs in the immediate neighborhood, and is magnesian limestone. All of the small piers standing in the river, except the one on the right of the pivot, have detached ice breakers. These ice-breakers are timber cribs filled with riprap, resting upon the river bottom; they are rectangular, with a triangular nose or starling, with a slope of 2 on 3; dimensions on top 12 feet wide, 19 feet long, with the nose 9 feet, making whole length 28 feet on top. All of these ice-breakers, except the one to the pier on the left of the pivot, are placed on a line, making an angle to the left of 15 degrees with the axis of the piers. The pivot-guards or draw-rests are timber cribs, planked and weighted with riprap.

Superstructure.—The bridge is a wooden Howe truss; the short spans are 22½ feet high and 19 feet wide out to out. The draw-span is 9 feet high at the ends and 26 feet at the center. The bridge-truss was built by the Saint Paul and Sioux City Railroad Company. The draw is opened and closed by men with levers.

At the time of our examination, in September, 1876, the company were putting bents of trestle under each span, the bridge having become unsafe by the decay of the chords. This early decay (the bridge had been built but 6½ years) of the timber in the chords is said to be due to want of care in its selection, and to the use of oak wedges in the pine chords. The acid of the sap from the oak wedges is said to have caused decay in the pine. An examination of the chords where most decayed showed it had taken place to a greater extent about these wedges than in other parts, but whether more than is properly chargeable to the excess of moisture here, I cannot say.

The whole bridge superstructure, except the draw-span, was to be rebuilt in the winter of 1876–'77.

INFLUENCE UPON NAVIGATION.

In 1866, 1867, and 1868, the channel of the river was along the left bank at the foot of the rocky bluff from Williams's Ferry, 5,000 feet above the bridge, to a point 1,400 feet above the bridge; from this latter point the channel crossed to the right bank, reaching it a short distance below the bridge. This crossing was gradual through this distance, so that the piers of the bridge were nearly parallel with the current. This was the case when our current observations were made in 1868. At that time the piers were partially built, all of the foundations being

in, and the masonry built to the level of the water. The pivot-guards and ice-breakers were not then built. Current observations made in July, 1876, by Colonel Farquhar, United States Engineers, with the water at 3.1 feet above low water, show a marked change in the direction of the current. The "*crossing*" from left to right bank, instead of commencing at a point 1,400 feet above the bridge, commenced only 600 or 700 feet above, the current crossing the bridge axis obliquely, making an angle of 10 degrees with the axes of the pivot-guard and rest-piers.

This change in the direction of the current was due to the formation of a bar running out from the right bank above the bridge; the lower end of this bar, at the time of these observations, was within 500 feet of the bridge. This change has made the right draw opening unsafe, and it is never used by steamers descending the river.

ALTERATIONS TO LESSEN OBSTRUCTION TO NAVIGATION.

It is probable that the extension or recurrence of the sand-bar cannot be prevented without rectification of the river for some distance above the bridge. This the bridge company should be compelled to do for the sake of the navigation on the Minnesota River.

HIGH BRIDGE.

High ground could have been found for the approach on the left bank where the width of the valley would have been but 3,300 feet. This length of approach is small in a high bridge over so large a stream as the Mississippi at this point. A continuous bridge here should not be less than 77 feet above low water.

SAINT PAUL HIGHWAY BRIDGE.

(This bridge was commenced in 1857, and completed and opened for travel in 1858.)

Authority.—The building of this bridge was authorized by the Territorial legislature of Minnesota, by act approved March 4, 1854. This act is entitled "An act to incorporate the Saint Paul Bridge Company." Section 12 of this act, which contains the provision fixing length and height of spans, and provisions in reference to navigation, is as follows:

> Said bridge shall be of such material as the stockholders may deem expedient, and shall be so constructed as to cover the main navigable channel of the river by a span at least three hundred feet from pier to pier, the lowest part of which said span shall be at least sixty feet above high-water mark, and said company may construct other abutments, piers, and guards to said bridge, at such distances from each other and at such places as may be deemed necessary, either on the street from which such bridge shall lead, on the island opposite said street in the said river, or on the mainland on the opposite side of said river: *Provided*, That nothing in this section shall be so construed as to warrant the obstruction of any public street or the navigable channel of said river.

The span over the main channel was built 240 feet long instead of 300 feet, as provided by the act. I have not been able to find that any additional legislation changed the provisions of the act here referred to.

DESCRIPTION OF THE RIVER AND VALLEY AT THE LOCALITY.

(See Diagram 4.)

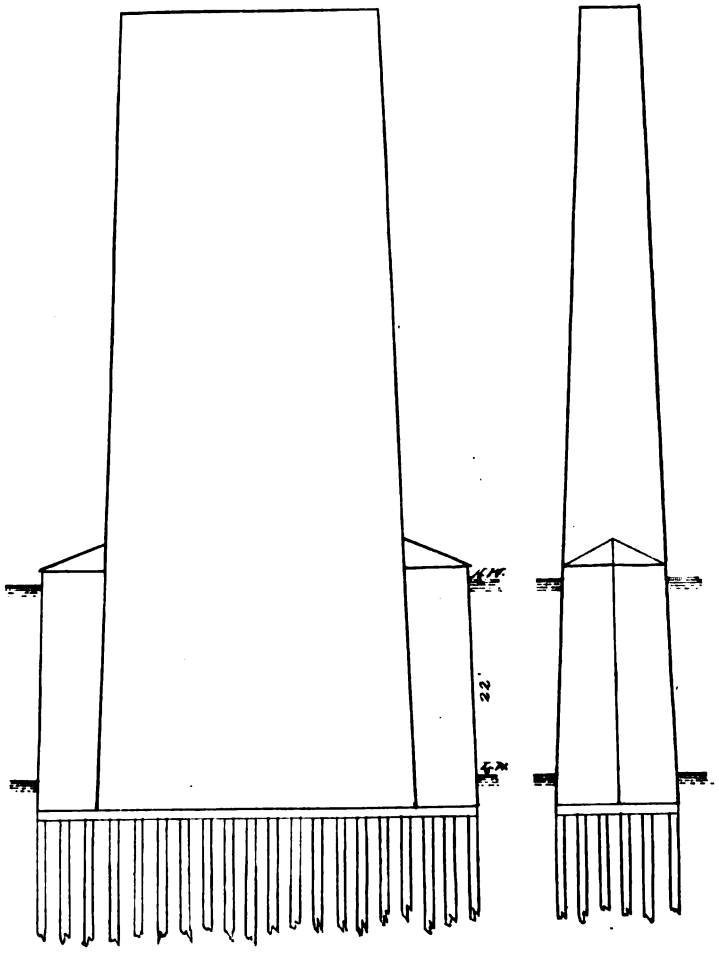
The Mississippi River, at the site of the bridge, is divided into two channels by an island. The distance between the low-water banks on

St. Paul, Minn.

ELEVATIONS OF PIER 2.

Scale of Feet

0 10 20 30



AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS)

the line of the bridge is about 1,200 feet. The usual low-water width of the river is about 800 feet. The high-water width from bluff to bluff varies from 3,000 to 6,000 feet. The bluffs are of sandstone, capped with limestone, and are about 125 feet high. The bottom land is overflowed at high-water from 8 to 10 feet or more. The current is, at time of low water, gentle at the bridge; at high water it is about 6 miles per hour. The rise from low to high water is about 22 feet. The slope is 0.9 foot per mile.

SURVEYS.

In September, 1866, a survey was made of the river from the mouth of the Minnesota, 6 miles above, to Red Rock, 7 miles below. This survey consisted in a determination of the low and high water banks, the slope of the water's surface, soundings, and observations for volume of discharge. The object of the survey was to gain a knowledge of the river to enable me to plan works for the alleviation of the difficulties attending navigation at low water.

In 1867 observations were made through nearly the whole season near this bridge, for volume of discharge. The survey of the river was continued from Red Rock to Hastings.

In 1868 special surveys were made at this bridge, including soundings and current observations.

The bed of the river at this bridge is composed of sand. The rock appears on the left bank, rising to the height of 90 feet above low water, almost perpendicularly.

DESCRIPTION OF BRIDGE.

(See Diagram 6.)

Commencing at the bluff on the right bank, we have an embankment about 1,600 feet long, built about 4 feet above high water; through this embankment were three openings of about 45 feet each. From the end of the embankment to the first pier was 375 feet of trestling in bents 30 feet apart; then 7 spans 140 feet long from centers; then the channel-span, 240 feet, and a span of 80 feet over the railroad and highway along the bank of the river.

Grades.—The roadway on the trestle and short spans to the right of the channel-span is on a grade of 1 on 20. The part on the channel and short span to the left is on a grade of 1 on 28.

Substructure.—The trestling is of the usual kind, fine timber formed in bents. The first pier on the right bank rests upon grillage of timber placed below low water. This pier is rectangular, 20 feet long and 5 feet wide on top, with a batter of half-inch to the foot. The others are 7 feet wide with the same batter. Those standing in the river have triangular ends up to highest water; these rest upon piles cut off below low water. The two piers standing on the island are rectangular without starlings, and have no piles under them. The masonry rests upon the grillage which rests upon a bed prepared by throwing in riprap. The safety of these piers and the three spans resting on them depends upon the preservation of the island. Since the erection of the bridge, from 150 to 200 feet of the island have been washed away. This washing is probably due to the filling out on the left bank in Saint Paul. The importance of preserving this island has been frequently brought to the attention of the city authorities, but up to October, 1876, but little had been done towards it. The channel piers (see Diagram W) are 30 feet long and 7 feet wide on top, 86 feet above low water, with a batter

of half-inch to the foot. The shore end of the 80-feet span rests upon the rock of the bluff upon which this part of the city of Saint Paul is built. The piers of the bridge are of masonry, from stone quarried in the bluff on the right bank about three-quarters of a mile above the bridge. This stone is magnesian limestone; it lies here immediately above the soft sandstone, generally in thin layers. It is used in many of the buildings of Saint Paul, and stands exposure very well when laid with its quarry-bed down. If laid differently it disintegrates rapidly by the infiltration of water between the strata, and the action of the frost. The up-stream starling of the right pier of main span has had pieces knocked off of it by floating logs and ice. This part of these piers should have been of more durable stone.

Superstructure.—The original structure was built of wood, by Mr. J. S. Sewell, civil engineer, in 1857 and 1858, of a peculiar pattern, designed by him. All of the spans except the channel span were deck-trusses with roadway on the top chord. The channel span is a through span; its lowest part is 63 feet above high water. A peculiar feature of this bridge is the grade of the roadway. The roadway, at the end toward the right bank of each span, is on the upper chord, and at the other end 7 feet above; the next span is placed 7 feet above the other, and so on to the channel span.

The main span was rebuilt of wood in 1869 and 1870, and the others replaced with iron spans in 1870. In 1875–'76 the channel span was replaced by an iron one. The bridge was built by a company and toll charged for its use; it has since passed into the control of the city of Saint Paul and is now a free bridge.

INFLUENCE UPON NAVIGATION.

This bridge, when built, was practically no obstruction to either raft or steamboat navigation. At that time the only means of reaching Saint Paul and the country above was by the river, and steamboat navigation was very flourishing. This accounts for the satisfactory provision made for it.

The first railroad communication to Saint Paul was late in 1867, nine years after the opening of the bridge.

The filling out on the Saint Paul side below the bridge occupies a part of the approach to the channel span, and deflects the current toward the island, making the shore part of this span in a slower current than the part toward the right pier. This filling out has not, as yet, greatly impaired the safe passage of this bridge by steamers, but if allowed to go on it will seriously injure it. Had the same amount of filling been above instead of below the bridge it would have obstructed the passage of this bridge very much.

There is much need for doing something on the Mississippi to prevent such injury to navigation, and secure it against the injury which parties, other than the bridge companies, cause to it, in the vicinity of the bridges.

HASTINGS RAILWAY DRAW-BRIDGE.

(Opened for railway travel in 1871.)

Authority.—The only authority for the building of this bridge, known to me, is an act of the legislature of Minnesota, approved February 7, 1867, entitled—

AN ACT to incorporate the Hastings, Minnesota River and Red River of the North Railroad Company.

SECTION 22. * * * This corporation are hereby authorized and empowered to extend their road by a bridge across the Mississippi River, and to farther extend and

construct and use their road with all its appurtenances to the mouth of the Saint Croix, and build and construct a bridge across said river to the town of Prescott, in Wisconsin, if they shall deem it expedient to do so, provided that said bridges across the Mississippi and Saint Croix Rivers shall be so constructed as not to obstruct the navigation of said rivers.

The name of this company was afterwards changed to the Hastings and Dakota Railroad Company.

All the bridge companies that have built bridges on the Mississippi, below the junction of the Saint Croix, where its channel forms the boundary line between the States, and over the Saint Croix River (where it forms part of the boundary between Wisconsin and Minnesota), have thought it necessary to have them declared post-routes by act of Congress.

On the part of the Mississippi which lies wholly within the State of Minnesota such action of Congress has not been sought, nor have the bridges been built according to the provisions of any act of Congress. There seems to be no reason, however, why any such exception should be made.

DESCRIPTION OF THE RIVER AND THE VALLEY IN THE LOCALITY.

(See Diagram 7.)

The river, which at low water for two miles above runs along at the foot of the rocky bluff of the left bank, crosses just above the town and strikes the low rock bluffs of the right bank, making there a sharp bend. The river is thus thrown into one narrow channel, which at low water is but 400 feet wide with a depth from 18 to 22 feet. A similar case is presented in the bend above the town of Hannibal, Mo. The rise from low to high water is 22 feet. The current is gentle. The high-water river, which extends from bluff to bluff, is about 4,000 feet wide; this is less than the general width of the valley in the vicinity and narrower than at any place below. The low rock of the right bank gives an easy and secure approach; the narrow low-water river requires only a minimum of bridging; and the river bend allows the railroad to cross the valley with but little deviation from the general alignment; so that this is an unusually economical site for bridging the river.

SURVEYS.

In September, 1866, a survey was made from Hastings, Minn., to Prescott, Wis., covering about 4 miles of river, the water at the time being about 2½ feet above low water. Both shores were surveyed, levels run, soundings made, and volume of discharge measured. In October, 1867, a survey of the river from Saint Paul to Hastings was made. This survey covered a small portion of the river surveyed in 1866. In September, 1876, a survey of the river at the site of the bridge, and current observations, were made, with the water 3.85 feet above low water.

DESCRIPTION OF THE BRIDGE.

(See diagram 8.)

Commencing on the right bank the approach is an embankment of 300 feet; then 235 feet of trestle to the right rest pier; then a draw-span of 300 feet over all, two spans of about 150 feet each, and one of 106 feet; then 2,286½ feet of trestling to a bridge of two spans, each 105 feet; then trestle for 700 feet to the embankment. The bridge is on a straight line from right bank to 160 feet beyond pier 6, numbering from

right bank toward the left; then a 2° curve for about 1,950 feet; a tangent to this curve is nearly parallel with the bank of the river above. From the end of this curve it is on a straight line across the short bridge to the bank of the river above.

Grades.—The grade of the road is level from the right bank to the end of the bridge, and then descends at the rate of about 15 feet per mile for 1,800 feet; then level across the short bridge to the embankment.

Substructure (see Diagram X).—The piers are built of the magnesian limestone found in the vicinity; the most of it from Barn Bluff, at Red Wing. They all rest upon piles sawed off, I was told, below low water. The draw-rest piers are 7 feet wide under coping; the others in the river 6 feet wide; those of the short spans near the bluff 5 feet wide. The draw pier is 26⅔ feet in diameter on top with a batter ½ inch to the foot. The rest piers are each 7½ feet wide on top, 21 feet long, with triangular ends 5½ feet long each; making total length 32 feet. The batter of these piers is ½ inch to the foot. The pier at right end of draw rests upon the rock of the natural bank, some 6 feet above low water and about 15 feet from the shore-line at low water, reducing the water-way to this extent. The rest pier at left end of draw (No. 3) has the same dimensions on top, but has a starling commencing 18½ feet above low water with a slope of 1 on 1.

The next pier left (No. 4) is 6 feet wide on top (under coping) and 30¾ feet long, including the triangular ends, the rectangular portion being 21 feet. This pier has a starling of same dimensions as No. 3. The next two piers to the left are of same dimensions without starling. The three piers of the short bridge in the north approach are 25½ feet long and 5½ feet wide on top. Their ends are semicircles in plan with a radius equal to half the width of the pier, the rectangular portion being about 20 feet long. The draw-rests are cribs resting upon the bottom of the river. They are about 20 feet above low water. The lower one is tilted, probably by reason of scour at the time of sinking it. This tilting amounts to a difference of 1½ feet in the elevation on the opposite sides of the lower end.

Superstructure.—The draw-span and two adjoining 150-feet spans have iron trusses of the Post pattern. They were built by the American Bridge Company of Chicago. The three 105-feet spans are of a combination of wood and iron and of the same form of truss. The draw is worked by men with levers. The lowest part of the structure is 8½ feet above the high water of 1870, and extreme high water is at least two feet higher.

INFLUENCES UPON NAVIGATION.

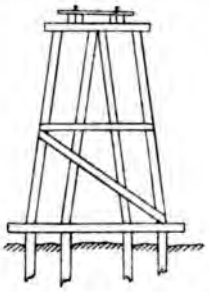
The left draw-opening is 130 feet in the clear, and the right draw-opening 115 feet; the clear width of this span is decreased by the rest-pier being placed on the bank some 15 feet from the shore. The two spans next to the draw are about 140 feet each in the clear. The locations of the bridge immediately below a very sharp bend in the river prevents it being seen by descending boats until within about 1,600 feet—too near for heavily-loaded boats to approach, especially in time of high water and swift current, and wait for the opening of the bridge.

ALTERATIONS TO LESSEN OBSTRUCTIONS TO NAVIGATION.

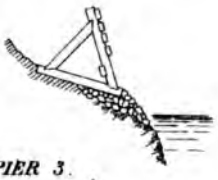
A sheer or fender has been built along the right bank up as far as the head of the draw-rest. The passage of the bridge would be improved if

Hastings, Minn.

TRESTLE BENT

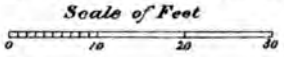


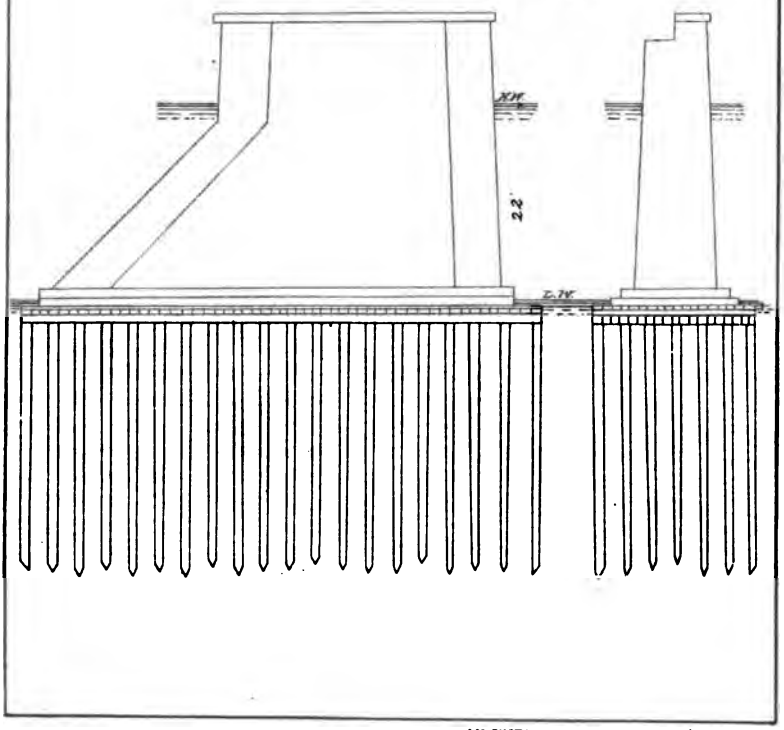
SHEER



ELEVATIONS OF PIER 3.

Scale of Feet





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this sheer were extended up river so that boats could land against it and drop through. Another reason for extending this sheer is that the shore is so rocky that to drop down against it is to endanger boats or rafts.

A signal placed above the bend so it could be seen from a boat coming down, before she got too near the bridge, would give time and space to land above the bridge if it could not be opened for its passage. This signal could be operated from the bridge, and would not be expensive.

HIGH BRIDGE.

A high bridge at this place would have high ground on the right bank at a short distance from the river. The approach on the left bank could be made for the most part on the present line and require but little increase in the length of the trestling. One span of 300 feet would be all that need to be high. This should be 55 feet above high water, which would be about 77 feet above low water.

WINONA RAILWAY BRIDGE.

(Opened for travel in 1871.)

This bridge was built by the Winona and Saint Peter's Railway Company in 1869–'70, under the authority of the act of Congress approved July 25, 1866.

GENERAL DESCRIPTION OF THE RIVER AND VALLEY.

(See Diagram 9.)

Winona is situated on a sand and gravel terrace on the right bank of the Mississippi whose level is but a few feet above the extreme flood-heights, and at high stages the water passes behind the town, and between it and the bluff. The channel has been permanent along this terrace where the bridge is situated. The ordinary water-way is divided by a low wooded island, near the lower part of which the bridge crosses, but the island is overflowed to a depth of several feet at high water. The ordinary width of the main water-way at the bridge is 1,000 feet, that of the lesser one 700 feet. There were two other smaller sloughs or water-ways running through the low banks on the left bank, forming water-courses at medium stages, while at highest stages the whole bottom overflows to a depth of several feet.

The width of the river between the bluffs (which are near 400 feet high and composed of sandstone and limestone, some of which answers for building) is about 3 miles. The rise from low to high water at this place is about 17 feet.

The slope of the surface at common low water averages about $\frac{7}{10}$ feet per mile; and the current is about 3 miles per hour at a stage 5.4 feet above low water. We have no measure of it at high water.

SURVEYS.

This locality was surveyed by us in September, 1866; again in October, 1867 (this latter time forming the terminus of a continuous survey from Lake Pepin); again in 1868, at which time the railroad company had obstructed the water-course on the Wisconsin side of the island with piles; and finally in September, 1876. All these are shown on our maps.

None of the surveys but the last was made after the bridge was built.

DESCRIPTION OF BRIDGE.

(See Diagram 10.)

Arrangements of spans and approaches.—Commencing on the west bank, the bridge is reached by trestling for about 2,100 feet, on a maximum grade of 1 in 100, crossing two streets now in use on trusses 40 feet long.

The first span is 80 feet from centers. It is a Howe truss. The next going east is the draw span which is 360 feet over all, giving clear openings of 160 feet. This span is of iron and is of the Post patent.

The next two spans are each 250 feet from centers, and are Howe trusses. This brings us across the main river to the low island. For the next 1,000 feet, trestling was used up to the time of our survey; it was then being replaced by 7 spans of wood, each 142½ feet in length. This was made necessary by reason of the scour about the piles on which the trestle rested. Driftwood lodged against them at time of high water, and scour took place to such extent as to endanger the structure.

The slough is crossed by Howe trusses, 4 spans of 160 feet each from centers. Then come 9 queen-post trusses, of about 45 feet length, each resting upon piles. There is then 487 feet of embankment over bottom-land to a slough 360 feet in width, crossed by pile trestling. This is to be replaced the coming winter (1876–'7,) by two trusses of 142½ feet span, and one of 45 feet. Then comes an embankment 2,805 feet, then 75 feet of trestling, then 2 spans of 132½ feet, and then 345 feet of trestling across the slough to embankment, making 3,988 feet of bridging exclusive of the trestle approach on the west bank. The draw of this bridge is turned by a small steam-engine placed on the turn-table. Provision is also made to turn it by hand.

Substructure.—The piers, commencing on the west bank, are of the following dimensions: The first, at west end of the 80 feet span, Howe truss, is of masonry, resting upon piles. It is inside of the low-water line, and is protected by riprap.

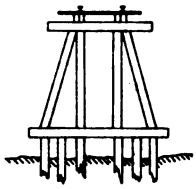
The second pier, upon which the west end of draw rests, is 30 feet long and 8 feet wide, under the coping. The starling on the upper end of the pier, commences 8.8 feet below the top.

The lower end of the pier is square. The batter, on sides, ends, and starling, is about $\frac{1}{24}$. The pivot-pier (No. 3) is 33 feet in diameter on top, with a batter of $\frac{1}{24}$. The guard rests are cribs resting upon piles, sawed off at about 4 feet above low-water surface; they are 22 feet wide 34 feet from the pier. From the guard-rests a row of piles, capped, runs to the middle of each side of the pivot pier, where they are 3 feet outside of the masonry.

The next pier east (No 4) is of the same dimensions as No. 2, except the starling, which has a greater slope, probably 4 inches to the foot. The next pier, No. 5, is 7 feet wide under the coping, but in other respects the same as No. 2. These piers all have cribs around them filled with stones, which come up to within about 2 feet of the water's surface at time of survey, and they have detached ice-breakers. The next pier is of timber 37 feet long by 11 feet wide, resting upon what appeared to be a crib, filled with riprap, with other riprap thrown in around it on the river side 15 feet wide at a level, 6 feet above low water. The next 6 piers across the island are each three trestle bents resting upon piles cut off one foot above present water. (See Diagram Y.) These bents are planked up on the outside to 10 feet above low water and filled with riprap. The entire length on the bottom is 39 feet including the triangular nose, above which is 6 feet up-stream end and 4.8 feet down stream. The up-river triangular nose is of 3-inch oak

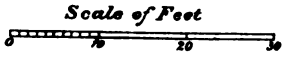
Winona, Minn.

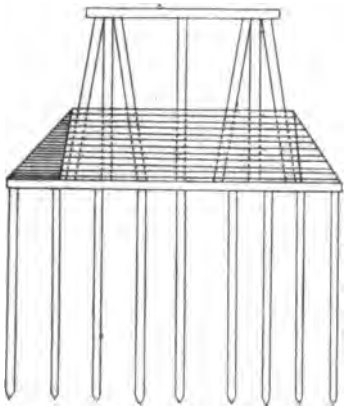
TRESTLE BENT



ELEVATIONS OF ISLAND PIER 10.

Scale of Feet





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plank, laid flatwise. The width of the pier on the top is 6 feet and its length about 24.

The next pier, No. 12, is on the west bank of the slough. It is composed of 40 piles in 4 rows. Around these piles a crib was built and filled with riprap. A large mass of riprap was also placed about the crib. The piers on top are 21 feet long and 10 feet wide. The crib is about 45 feet long and 15 feet wide. These piers make an angle of about 75° with the axis of the bridge inclining to the right-hand side, looking up stream.

Detached ice-breakers are built above each of the piers in the slough, 33 feet long and 14 feet wide. They are of two rows of piles driven close together, capped and walled. The nose is triangular, forming 9 feet of the length and planked. The cut-water is covered with railroad iron. The whole is filled with riprap up to the top, 13 feet above low water. The lower end of ice-breaker is 82 feet from upper side of bridge, in prolongation of the center line of pier. Around the ice-breaker the riprap extends out about 10 feet on all sides above water, at time of survey.

At each of the shore piers (Nos. 12 and 16) a sheer has been built. The west sheer is 300 feet long and the east 176 feet long. They are of two rows of piles, capped, about 16 feet above water at time of survey, with riprap thrown against and between them, and they flare so as to as to turn drift into the open spans.

Beyond the sixteenth pier come the nine queen-post trusses, resting upon bents of piling, recently built in place of pile trestling that had become too much decayed to be trustworthy.

The piers of the slough bridge consist of three rows of piles with riprap around and between them. These piers have the general direction of the slough, and make an angle of 73° with the axis of the bridge.

INFLUENCE UPON NAVIGATION.

Steamboats.—The piers of this bridge were parallel with the current at the stage when it was examined by us. The arrangement of the draw-spans are practically next the shore (the right bank), following the example of the Rock Island bridge.

The arrangement of the pivot pier and its guards is not good. The projections at the pivot are bad to strike against, especially if going at any ordinary speed.

Rafts.—Large rafts are compelled to divide in two parts to pass. There is some difficulty occasioned by reason of a sand-bar about 2,000 feet above, which sometimes closes down to near the right bank, and here Yeoman's boom occupies a desirable part of the navigable channel, from which it should be removed. The sides of the pivot pier and guards are not as smooth as they should be to prevent injury to rafts in rubbing along them. The landings made along the shore leave it too jagged for safe passage of rafts. It seems probable, too, that the span left for rafts at high water in the water-way west of the island is too narrow.

ALTERATIONS TO LESSEN OBSTRUCTIONS TO NAVIGATION.

Sheer-booms.—The board of engineers on sheer-booms recommended that Yeoman's log-boom be drawn in towards the right bank at least 100 feet, and that a sheer-boom be placed above the bridge with its lower end at the right rest pier, extending up stream 150 feet above the elevator.

Pivot pier guards.—These guards should be rebuilt so as to have the same width the whole length from the draw-rest above to the one below the pivot. Floats should not be used as guards, which should be framed and planked up to 4 feet above high water.

HIGH BRIDGE.

A high bridge at this site would require long approaches on both sides' because the banks are low. The least height should be 75 feet above low water, or 58 above high water.

If a high bridge is built, the best location is at Trempealeau, about 12 miles lower down on the river, where high banks, about 3,500 feet apart, are found on both sides. A single bridge here might have been made to accommodate the railroads approaching both Winona and La Crosse.

LA CROSSE RAILWAY BRIDGE.

(Opened for travel in December, 1876.)

Authority.—By act approved February 21, 1868, the Southern Minnesota Railway Company were authorized to construct and operate a railroad bridge across the Mississippi River, between the city of La Crosse, Wis., and a point opposite in the State of Minnesota, under the same general provisions as were contained in the act approved July 25, 1866, authorizing the bridge at Quincy. No bridge has been built under the act of February 21, 1868.

By act approved April 1, 1872, the Milwaukee and Saint Paul Railway Company were authorized to build a bridge at any point they may select between the county of La Crosse, Wis., and the county of Houston, Minn.

The only essential differences between this act and that approved July 25, 1866, are embraced in sections 4 and 5, which are as follows:

SEC. 4. That all railway companies desiring to use said bridge shall have and be entitled to equal rights and privileges in the passage of the same, and in the use of the machinery and fixtures thereof, and of all approaches thereto, under and upon such terms and conditions as shall be prescribed by the Secretary of War, upon hearing the allegations and proofs of the parties in case they shall not agree.

SEC. 5. That the structure herein authorized shall be built and located under and subject to such regulations for the security of navigation of said river as the Secretary of War shall prescribe; and the said structure shall be at all times so kept and managed as to offer reasonable and proper means for the passage of vessels through or under said structure; and the said structure shall be changed at the cost and expense of the owners thereof from time to time, as Congress may direct, so as to preserve the free and convenient navigation of said river. And the authority to erect and continue said bridge shall be subject to revocation, modification by law, whenever the public good shall, in the judgment of Congress, so require, without any expense or charge to the United States.

The act approved June 4, 1872, still further increased the discretionary power of the Secretary of War; this was as follows:

AN ACT regulating the construction of bridges across the Mississippi River, approved June 4, 1872.

Be it enacted, &c., That all bridges hereafter constructed over and across the Mississippi under authority of any act of Congress, shall be subject to all the terms, restrictions, and requirements contained in the fifth section of the act to authorize the construction of a bridge across the Mississippi at or near the town of Clinton, Iowa, approved April 1, 1872; and in locating any such bridge the Secretary of War shall have due regard to the security and convenience of navigation, to convenience of access, and the wants of all railways and highways crossing said river.

A design for bridging the Mississippi River about two miles above La Crosse, near the lower end of Minnesota Island, was submitted to the Secretary of War, on May 23, 1872, by the president of the Milwaukee and Saint Paul Railway Company. This location was opposed by the

city of La Crosse, and remonstrance was made to the Secretary of War against the adoption of it. This opposition desired the bridge located below the mouth of Black River, and centrally as regards all the railway and highway interests, so that there might be but one bridge. The whole matter was referred to me by letter from the office of the Chief of Engineers, dated June 8, 1872. I submitted a report dated June 29, 1872. The general view taken was that the opposing interests should settle their differences among themselves. The subject was then referred to a board of engineers, of which Col. J. N. Macomb was president. They submitted one report dated July 29, 1872, and a second report dated September 26, 1872. The board favored the location at the town.

The papers relating to the whole subject were printed as Ex. Doc. No. 71, H. R., Forty-second Congress, third session. It is very interesting, as it presents in detail a phase of the complications which attend the construction of bridges that will be the least obstruction to navigation. These reports, omitting some of the accompanying documents, are printed in the Annual Report of the Chief of Engineers, 1873, pp. 553–577.

In 1875 the Milwaukee and Saint Paul Railway Company were allowed to proceed in the construction of the bridge at their own location.

GENERAL DESCRIPTION OF REGION ABOUT LA CROSSE.

(See Diagram 11.)

La Crosse is built upon the east bank of the Mississippi, on a sandy terrace, elevated from 10 to 40 feet above the floods. This terrace extends many miles up the valley, being cut through by the La Crosse and Black Rivers, but terminates about 4 miles below the city. At the city this terrace is about 2½ miles wide, and this is the only place where it touches the permanent channel of the river. There is also a similar terrace, of less extent, on the west side of the valley, but the two are separated by about 2 to 2½ miles of intervening bottom-lands, islands, and river. The river rises, from lowest to the highest stages, about 16 feet.

The islands and bottom-lands are of sand and mud, in most places deeply inundated at high water, and many lakes and marshes exist at nearly all times. The distance between the sand terraces (2 to 2½ miles) gives a measure of the general extent of bridging and embankment for the approaches, the relative amounts depending upon different locations. The bed of the river is entirely of sand in this neighborhood, and no borings have been made to reach the rock beneath it. The depth of sand is probably not less, generally, than 70 feet.

The river slope is gentle and the current mild, varying from 2 to 3 miles an hour. The river is divided by islands, so as to nowhere flow in a single channel, and sometimes there are two of the principal of these that are nearly of equal width and depth. The nearest union of all the water in one channel occurs below La Crosse, between the small islands of La Plume and Broken Arrow, a place formerly much used by the Dakotas or Sioux as a crossing-place (*Traverse de Sioux*). This has been so permanently, from time immemorial, and here the Southern Minnesota Railroad Company locate their crossing. A large island opposite La Crosse is known as Grand Island, and the city people want the bridge there. A considerable island above this, known as Minnesota Island, across the foot of which the Milwaukee and Saint Paul Railroad Company located their bridge, divides the river nearly equally. Its name indicates that the main low-water channel is or was on the Wisconsin side of it. The law fixing the boundary of the two States makes it the

main channel of the river, and the lines of the Minnesota land surveys were extended over this island. It is probable that by artificial works the main low-water channel could be kept permanent on either side of this island.

The distance between the main bluffs bounding the valley is from four to four and a half miles. These bluffs are in the neighborhood of 400 to 450 feet high. They are composed of magnesian limestone of the Silurian epoch, and nearly horizontally stratified. The heights of these bluffs give a good idea of the ascent and descent a railroad line must make in crossing the valley between two points of the interior, east and west of the river.

The low-water channel is at the foot of these bluffs on the west side, about six miles above La Crosse, and again on the west side, about ten miles below, at Brownsville, Minn. These high bluffs bordering the valley make it a matter of some difficulty for a railroad to get from the river-banks up to the level of the high prairie, except along the valley of an affluent to the main river.

On the west side of the river the Southern Minnesota Railroad has a good approach in the valley of Root River, Minnesota, which debouches into the Mississippi a few miles below La Crosse, leading in a westerly direction. The valley of Pine Creek, Minnesota, debouches opposite La Crosse, leading out in a northwesterly direction, and this is said to be the line chosen by the Saint Paul division of the Dubuque and Minnesota Railroad. The valley of the Mississippi itself furnishes good routes for roads leading northwesterly, and both sides are already selected for roads, the left bank being taken for the Milwaukee and Saint Paul Railway.

On the east side of the Mississippi the valley of Black River opens out to the northeast. The valley of La Crosse River, coming into the Mississippi Valley about two and a half miles above La Crosse, furnishes the route for the railroad eastward to Milwaukee. Any other road to the east will probably have to go down the Mississippi Valley in a southeasterly direction till some suitable tributary valley is reached.

SURVEYS.

In October, 1866, a survey of about four miles of river, commencing about two miles above and extending two miles below La Crosse, was made by us. At that time bridges were contemplated but none had been authorized. The river was about 2.5 feet above low water. The slope per mile was 0.35 foot. This survey commenced near the site since chosen by the Milwaukee and Saint Paul Railroad Company for their bridge.

In September, 1876, we made surveys and examinations at this place while the bridge was in process of construction. The water was two feet above low water. The rise from low to high water is given by the bridge engineers as 14 feet, but this seems too little. The high-water mark of 1859 on Coon's warehouse, in La Crosse, was 13.83 feet above the surface of the water in October, 1866, and as higher waters than that of 1859 have occurred in this part of the river, as determined by marks in the river above, we concluded that the range must be greater, probably as much as 16 feet.

DESCRIPTION OF BRIDGE.

(See Diagram 12.)

Approaches and arrangement of spans.—Commencing at North La Crosse, there is an embankment 1,420 feet in length to the Black River;

then 600 feet of pile trestle to a pivot-draw span; this span is 310 feet over all; then 1,900 feet of trestling to French's Slough; the bents of this trestling are 16 feet apart and rest upon 4 piles sawed off about 3 feet above surface of the ground. French's Slough is now crossed on trestling, but the company propose to put in a 100-feet truss upon stone piers. From French's Slough to the old channel, 2,000 feet, there is trestling; of this distance, 1,125 feet is on a 2° curve, which ends 50 feet from the pier on the bank of the "old channel." This old channel is crossed by 5 spans of 148 feet each, total 740 feet; then 650 feet of trestling across Minnesota Island to the bridge, over what is now the main channel of the river; of this distance, 593 feet is on a 5° curve. The main channel is crossed by two spans of 164 feet each—one of 250 feet, and a pivot draw of 360 feet. This portion of the bridge is on a straight line, which extends 100 feet beyond the right or west abutment; then comes a 6° curve for 534½ feet, and then 4,340 feet tangent, extending to La Crescent junction; all on the west side of the bridge is trestle. The whole length between main line on east side of river and main line on west side is 13,540 feet; of this distance 1,420 feet is embanked on the east approach, leaving 12,120 feet of bridging and trestling. This trestling the company propose to replace by embankment to as great an extent as the requirements of high-water way will allow.

Grades.—The draw over the Black River is approached on an up-grade of one-half foot in a hundred; the elevation of rail by the railroad levels on the draw is 58 feet. The water's surface at time of survey, September 30, 1876, was 21.4 feet below the rail; the lowest part of the draw was 17.8 feet above the water. After crossing the bridge there is a down-grade of one-half foot to the hundred for 900 feet, descending to 53.5 of the railroad levels; then it is level 1,340 feet, until French's Slough is crossed; then an up-grade for 1,800 feet, where the elevation of 62.5 feet is reached, and this is the level of the rail on the bridge over the "old channel," and across Minnesota Island, and over the present main channel of the river.

Substructure.—Commencing with the trestling in the Black River approach (the trestling rests upon piles sawed off near the surface of the water), the bents are 16 feet apart from centers, except for the last 100 feet before reaching the Black River draw-span, where they are but 12 feet apart. Each end of this draw-span rests upon a pier of three rows of capped piles at right angles with the axis of the bridge. The center pier is of masonry resting on piles. It is 27¼ feet in diameter on top, with a batter of one-half inch down to one foot below present water's surface, where there is an offset of 6 inches. The top of the masonry is 11 feet 7 inches above present water, and 9 feet 10 inches below top of rail. The draw-span rests, when open, upon three rows of piles, above and below the bridge. Detached ice-breakers are placed above the upper guard-rest, and above the pile trestling. The trestling between the draw-span over Black River and the "old channel" rests upon piles sawed off about three feet above the surface of the ground. The bents are 16 feet apart from centers. The piers of the bridge over the "old channel" are six in number. The two standing on the banks are 22 feet long and 5 feet wide on top. The four standing in the "old channel" are 6 feet wide on top under the coping and 22 feet long, with a triangular starling on the up-stream end. The foundations of these piers is a grillage, 2 feet below low water, resting on piles. On this are three heavy courses of stone, making offsets of 6 inches. The cut-water of the starling then begins, and rises with a slope of 1 upon 1. The batter of the pier is 24 upon 1.

The top of the piers was 21 feet 8 inches, and the top of rail on trestle at pier on Minnesota Island 23 feet 6½ inches above the water at time of our survey. This trestle was just built and the rail laid when the measurement was made.

The bents are 14 feet apart from centers. The first pier on bank of the main channel is 21 feet long on top (under coping) and 6 feet wide, with a batter of ½ inch to the foot. This pier has no starling. Commencing at 3 feet below low water are three courses, each offsetting 6 inches on all sides; under this a grillage of timber of two courses resting upon piles.

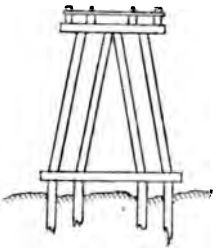
The other piers, except the rest-pier, east of draw, are of the same dimensions, except that they have starlings. The starlings are equilateral triangles whose sides equal the width of the pier. From a point 10 feet above low water the slope of the starling begins, 1 on 1, and is continued down to the first offset course. The east or left rest-pier is 23 feet long on bridge-seat, 27 feet 11¼ inches under coping, and about 38 feet immediately above first offset course. This course is 2 feet above low water; the bottom of the masonry is 3 feet below low water. (See Diagram Z.) At the time of our examination the shore pier on the island and the first one in the river were the only ones completed; the next pier was in process of construction. The east rest-pier and draw-pier had the piles driven only. The piles had been driven for both guard-rests, and the upper guard-rest built. This upper guard-rest is of 12-inch by 12-inch timber; it is 170 feet long and 32 feet wide, with two side compartments 8 feet wide each, and a center space of 16 feet. The outer spaces were to be filled with stone. The bottom of this rest is 9½ feet below low water. The starling commences 1 foot above low water, with a slope of 1 on 1, which is carried up to 10 feet above low water. The whole height above low water is 17 feet 4 inches. The pivot-pier is of masonry, and of the following dimensions: At 2½ feet below low water, 33½ feet in diameter; at 10 inches above low water (the top of offset courses) the diameter is 31 feet 3 inches; and at 15⅝ feet above low water (just under the coping), 30 feet; on the top (17 feet 10 inches above low water) the diameter is 31⅓ feet.

The piles in the main channel under the piers were driven by a "Nasmyth" hammer to a depth of about 40 feet below bed of river; those under the other piers were driven by a common pile-driver to a depth of from 20 to 25 feet.

Superstructure.—The superstructure, as far as erected at time of our survey, is as follows: The draw-span over the Black River, 310 feet over all, is all of iron, except the floor-beams, which are wood. It is about 22 feet high at the ends and 30 feet at the center. It has 11 panels each side of the center panel, which is 19 feet. This draw is turned by men with levers. But one of the openings can be used by rafts or steamboats, the right-hand one being obstructed by a shoal above, and by the wharf of a saw-mill immediately below. The draw is but little used by boats, the river being navigable for only a short distance above the bridge. The space above the bridge is used as a winter harbor and repair basin, and large shops are located there. This draw-span was required by a law of the State of Wisconsin. Over the "old channel" there are five spans of iron, built by the American Bridge Company of Chicago. These spans weigh about 70 tons each. They have each 10 panels. The height of truss is 22 feet. The floor-beams are suspended from the foot of the posts. These trusses seem very light, not quite 1,000 lbs. to the running foot; the ties cross one panel, or what is termed single intersection. This and the railway bridge at Louisiana

La Crosse, Wis.

TRESTLE BENT.



ELEVATIONS OF PIER 3.

Scale of Feet

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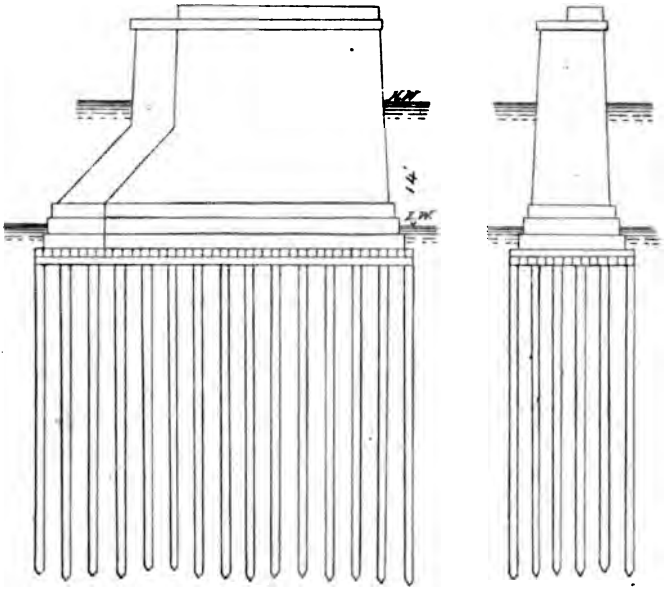


AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS)

are the only iron bridges on this river that are built with diagonals of single-panel length.

Accessory works.—The location of this bridge at a point where the river was divided into two nearly equal channels made the closing of the left or "old channel" to the east of Minnesota Island necessary to insure the navigation of the other, where the draw was placed. A dam was built at the head of the island, about 1½ miles above the bridge. It is inclined up stream from the head of the island, and is about 1,600 feet long; the width of the water-way closed is about 900 feet.

The head and shore of the island for a distance of about 3,800 feet have been protected by riprap. At a point about 3,000 feet from the head of the island the water broke through and ran into the "old channel." The difference of level in the two channels being a little over 1½ feet in a distance of 800 feet, gave it a rapid velocity. This opening was closed with brush and riprap. This dam was built in very cold weather in the winter of 1875–'76. The ice was cut on the line adopted for the dam, and a row of piles driven on the lower side. Against these were placed mattresses of brush and hay loaded with stone, and well covered with riprap after it reached the height of a few feet above low water. Although it was a success, it was a difficult and expensive operation. The thermometer being much of the time below zero, the ice formed rapidly in the opening made, so that it was impracticable to work along the whole line at once and cover the whole bottom with a layer and then follow it with successive ones. The work carried on from the ends caused deep scouring in places, and largely increased the amount of material required. The ice-bridge did away with the necessity for boats, but this advantage was more than lost by the trouble the cold and ice gave, and by reason of the short days of winter. The dam withstood the succeeding high water, and in low stages confined all the water to a single channel, and required its enlargement in order to restore the former area of section and velocity. With this requirement suddenly forced upon the new channel, it became engorged, and its slope and velocity increased. A more rapid movement of the sandy bed resulted, but still the latter motion was slower in effect than might have been expected. The consequence was, but a gradual change in line of the deepest water as the sand-bars moved down the stream, and sometimes the situation of the bars was such, with the water drawing directly over them, that it became a matter of difficulty for boats to follow the deep water between the bars. At the time of our examination the conditions were more favorable to navigation than they had been for some time previous.

It would have been more judicious to have waited until the new regimen had been established before building the bridge. It is contrary to good river engineering practice to suddenly close so large a channel at once, as was done in this instance. The proper way is to lay down a layer of mattresses about 2½ to 3 feet thick, weighted to hold them in place, entirely across the channel it is proposed to close. This would exclude but a part of the water, and while forming a receptacle for sand to lodge behind would force enough water into the other channel to produce a proportionate enlargement. After this object is reached another layer may be put across the channel to be closed, and its effect awaited. Perhaps the next time it might be closed entirely, but if not, the same process should be gradually continued until the end is reached. If the channel to be closed is of considerable length and capacity, layers of mattresses should be used along it at other points than the head.

INFLUENCES ON NAVIGATION.

When our examinations were made, the right draw space was the only one available for either boats or rafts by reason of the existence of a bar extending from near the upper end of the guard-rest to the left bank of the river. The maximum current in this span was as great as 4½ miles per hour.

During the summer the passage of the piers and accessory works had been attended with delay to boats and many accidents to rafts.

The bar on the right-hand side of the channel above the bridge had at one time advanced down stream so far as to leave only a narrow channel between it and the bar immediately above the bridge. The crossing from left to right bank between these bars was nearly at right angles with the channel above, and in running it rafts would sometimes be carried by the current upon the bar below, or upon the upper guard-rest. At the time of our examination there was a channel through the upper bar 6 feet deep, by which the approach to the bridge was nearly direct.

Great irregularities were found in the cross-section at the bridge, the right draw space having a depth of 26 to 28 feet, while in the other spans there was not over 11 feet; and in the sections above and below the bridge, at a distance of 800 to 1,000 feet away, the maximum depth was but 14½ feet, showing a probable scour of not less than 13 feet in this channel at the bridge. In sounding from a short distance above down through this draw opening the bottom appeared very irregular, there being one or more ridges with not more than 15 feet water upon them; these ridges seemed, from the limited examination given, to be covered with stone. This channel was fast increasing in width by undermining and caving of the bank until it was protected by a line of piles and rip-rap.

The current approached the axis of the bridge at an angle of 15° with the axes of the piers, except near the middle of the right-hand draw opening, where it was nearly direct. Immediately below the lower guard-rest the current sets toward the left bank.

ALTERATIONS TO LESSEN OBSTRUCTIONS TO NAVIGATION.

Whether any such will be needed, and to what extent, can only be found out after the work is completed, and we shall have to await the completion of the enlargement of the single channel before we can judge how the bridge will affect it.

HIGH BRIDGE.

By moving the site of the bridge about one mile above its present location, a high bank on the right side would furnish an approach to a high bridge. The opposite bank would be low. A high bridge at this point, on account of the rise being about 16 feet from low to high water, should be 75 feet above low water, or 59 feet above high water.

PRAIRIE DU CHIEN PONTON RAILWAY BRIDGE.

(Opened for railway travel April, 1874.)

Authority.—In the act approved July 25, 1866, section 6 provided "for a bridge from Prairie du Chien, Wis., to North McGregor, Iowa, subject to the same conditions" as fixed for the bridge at Quincy. This bridge was never built, probably because the division of the river into two good navigable channels, required two draw bridges.

Peculiar condition.—The river at this point is divided by an island, and is about 1¼ miles in width from shore to shore. Before the building of the bridge, passengers and freight were transferred by ferry which had to go around the head or foot of this island, making the distance from landing to landing nearly 4 miles. The freight cars were transferred on boats built for this purpose. This mode of transfer was slow and expensive when the river was clear, but when the ice began to form, and before it got sufficiently strong to cross upon, was very slow and difficult, and insomuch that sometimes nearly all the rolling stock would be accumulated at this point. Again in the time of the breaking up of the ice in the spring there was delay, though not usually so long as in the fall. To shorten this ferriage a pile-bridge was constructed across the island, and a boat used in each channel. From this time on, a train was run across the island from one channel to the other.

In the winter of 1868 or 1869, after the river had frozen over, piles were driven across both channels and the trains run through without delay until the ice broke up in the following spring, when the ferry was again resorted to. This continued until April 14, 1874, when the first train passed over the present pile and ponton bridge. A bill to legalize this form of bridge was introduced into Congress, and, on reference to the War Department, was reported upon favorably by Col. J. N. Macomb, United States Engineers, May 6, 1874. (See Annual Report of Chief of Engineers for 1874, Part I, pages 680–682.) The act was passed; approved June 6, 1874.

DESCRIPTION OF RIVER AND VALLEY AT THE LOCALITY.

(See Diagram 13.)

The right bank of the Mississippi River is high, rocky, and steep from the mouth of the Yellow River, 3 miles above North McGregor, to about 3 miles below, presenting no practicable approaches for a railroad from the west except at the towns of North and South McGregor. Opposite the town of South McGregor the river is all in one channel. The railroad, as first built to Prairie du Chien, terminated opposite, and here was the easiest place to build a bridge. For some reason the railroad changed the depot to about 2 miles up river to North Prairie du Chien and opposite North McGregor. Between this new terminus in Prairie du Chien and North McGregor the river is divided into two navigable channels by a large island, extending 3 miles up and down the river. The width across here, including the space occupied by the island, is about 1¼ miles. At the time of ordinary high water the width is about the same, but the island is completely submerged. Prairie du Chien is situated on a sand terrace, from which it derives its name, most of which is above overflow, the higher parts as much as 40 or 50 feet. Back of this sand terrace are high rocky bluffs, the distance between the bluffs being about 2½ miles. The current in this part of the river is gentle. The rise from low to high water is 22 feet. The bed of the river is sand, mud, and shells, and subject to but little change. The

lower part of the island, over which the bridge crosses, is nearly all occupied by a lake, with only a narrow strip of land between it and the channels.

SURVEYS.

In October, 1866, we made a survey of the river from the head of this island to and including the mouth of the Wisconsin River, a distance of 7 miles. This survey was of both channels, and covered all the river where it was feasible for a railroad to reach it from the west, to connect with that already built to Prairie du Chien. No location for a bridge having then been determined upon, the survey was general in its character. The slope and volume were measured, and soundings were taken throughout the whole distance.

In October, 1876, after the completion of the ponton bridge, a survey and observations for the direction of the current were made, the water at that time being about 6 feet above low water. This survey was confined to the immediate vicinity of the present structure.

DESCRIPTION OF THE BRIDGE.

(See Diagram 14.)

In this bridge the approaches and fixed portions across the channels and islands, are of piles. The openings in each channel, left for passing vessels and rafts, are filled by strong deck-scows called pontons, swung into position for the passage of trains, and left open at all other times. These pontons lie athwart the stream, and not like pontons in ordinary military bridges in the direction of the stream. The ponton in the last channel is made by uniting three ordinary transfer-scows, rigidly, end to end, each 131 feet long, 24 feet wide, and 6 feet deep, making, together, a length of 393 feet. The ponton in the west channel is a single-deck scow, specially constructed, 408 feet long, 28 feet beam, and 6 feet depth. The ponton in east channel, when in position in line with the piling, stands at an angle with the general direction of the current of about 55°. The up-stream end of the ponton is made fast to a dolphin (a clump of piles united together) in such a manner as to allow it to swing freely. The down-stream end is held in position by being fastened to another dolphin. On the down-stream end of the ponton is placed a small steam engine, provided with a drum around which a chain is passed. The ends of this chain are fastened to dolphins or group of piles, one above the ponton when closed and the other at the end of the ponton when open. When it is desired to open the bridge the pawl is thrown off of the drum and the current opens it in about one minute, the chain rendering around the drum. When it is to be closed, the engine is started and the drum turned in the opposite direction, and the ponton is brought into position in the bridge; this requires from 3 to 5 minutes. On the east ponton the rails are laid on a longitudinal stringer on the deck, and there is no appliance for raising and lowering the track, so as to suit different stages of water. Small changes in the height of water are provided for by short adjustable sections of track at each end, which serve as inclined planes, connecting the boat and the stationary track. This arrangement answers for but a limited change in the height of water. To meet the change in level, from high to low water, it was necessary to build two approaches, one for high water and one for low water, each about 2,100 feet long. The low-water approach being submerged in time of high water.

In the west or McGregor channel the ponton is so built as to allow of an adjustment for different stages of water, so that one approach serves for all stages. In this boat are two trusses running the whole length, these trusses rest upon the bottom of the boat and are 14 feet from outside to outside. They rise about 5 feet above the deck of the boat. The track is placed between these trusses and adjusted for the different stages of water by being blocked up as the water falls, and by the blocking being removed when the river rises. This ponton is operated in the same manner as that in the east channel, except that the steam engine is placed in a flat-boat 48 feet long and 16 feet wide, which is attached to the lower side near the down-stream end of the ponton.

The west channel, being the most direct, and protected by the high bluffs from winds, is the only one used by the rafts going below this point. To facilitate their passage through the bridge, and to turn the floating ice into the opening and keep it from the pile-trestling approaches, a set of dolphins have been driven above the bridge in lines running from the opening to either bank at a distance of about 1,000 feet on east bank and 500 feet on west bank. These dolphins consist of 12 or a less number of piles driven in a close group, held together by being waled near their heads. On the channel sides of these dolphins (extending 250 feet above the bridge on the west side, and 500 feet on the island side) there is a floating boom held to them by chains. These booms, near the bridge, are composed of four sticks, laid side by side; a little above, of three sticks, and then of two sticks, to their upper end.

In the east channel the only protection against ice is in dolphins at each end of the openings, and twelve dolphins in a line to the shore of the island from the west side of the opening. All of these twelve but the one nearest the island, were broken down last spring by the ice. These dolphins, while of sufficient strength to withstand any shock that they will be likely to receive, except from ice, are wholly inadequate as ice-breakers. It is probable that no ice-breaker constructed of piles alone would successfully resist the pressure of such ice-fields as they would be subjected to in this part of the Mississippi.

INFLUENCE UPON NAVIGATION.

This bridge is practically no obstruction to steamboat navigation. The current, at the time of our examinations, when the water was about 6 feet above extreme low, was but 1½ miles per hour in the east or Prairie du Chien channel, and 2 miles per hour in the west or McGregor channel, down which the rafts pass, the opening being sufficient for the largest ones.

The booms above aid to direct the rafts into the opening when they are but a little out of direction, or when they strike at only a small angle, although they are sometimes considerably broken even then. If in any way the raft gets such direction as to strike it at a large angle, it will be much broken up. Experience here shows that fixed sheer-booms cannot guide rafts without subjecting them to injury.

The opening in the east channel is 393 feet on line of ponton, but the available distance is but 345 feet between the two dolphins at the ends of the ponton. The clear distance at right angles with general direction of the current is this distance into the sine of the angle of 58° which it makes with the direction of the current—sine 58° into 345 = 293 feet as the available opening in east channel between the dolphins. The clear opening in the west or McGregor channel is the distance along the line

of the ponton into the sine which it makes with the general direction of the current—sine 55° into 408 = 334 feet clear opening at right angles to the general direction of the current. These pontons are removed in winter, and the openings filled with piling, making a complete pile-bridge, until the river opens in the spring.

GENERAL REMARKS.

This novel bridge was designed and constructed by Mr. John Lawler, of Prairie du Chien, Wis., to meet the practical wants of the transfer at this locality. He has also built one at Stillwater, Minn., across Saint Croix River Lake. It appears well adapted to places like these where the current is not strong.

On Lake Champlain is a similar bridge with a ponton draw 300 feet long, 30 feet wide, 12 feet high, draught 2 feet. It is connected by hinges with a pier, and is swung by means of chains. (See Van Nostrand, vol. vi, p. 221, February, 1872.)

One of the difficulties in the application of this kind of bridge is the change in level from high to low water, which in these localities is about 20 feet. Floating ice is another difficulty attending its use, but at these places the river closes and opens with so brief an interval of moving ice that the inconvenience is not long felt, although it is during its continuance the greatest trial to which the bridge and its management are subjected.

There appears no reason why the pontons could not be made in the ordinary manner of several boats lying, when in position, in the direction of the current and supporting a continuous truss on which to receive the passing trains. Such an arrangement could be made to give greater lateral stability with the same flotation than the method used by Mr. Lawler, and while in position small cakes of floating ice and drift of ordinary kind could readily pass.

HIGH BRIDGE.

A high bridge at this place would have to be 77 feet above low water. It would have high ground for the McGregor approach, and on the Prairie du Chien side the ground is above high water. It would have to have high, long spans over both channels, and it would make a very long, expensive bridge. The location at South McGregor would avoid this, the river there being all in one channel. Another good location for a bridge would be found at the mouth of the Yellow River. The valley of this stream would furnish a location for a railroad with easy grades and good alignment, both of which are wanting in the McGregor ravines.

DUBUQUE RAILWAY DRAW-BRIDGE.

(Opened for travel December, 1868.)

Authority.—This bridge was built in 1868 by the Dubuque and Dunleith Bridge Company, under act of Congress approved July 25, 1866.

DESCRIPTION OF THE RIVER AND VALLEY AT THE LOCALITY.

(See Diagram 15.)

It crosses the river from Dunleith, Ill., to Dubuque, Iowa. The Mississippi at this point is about 1,700 feet wide between the banks; above,

for 2,000 feet, it is about 1,300 feet wide. Immediately below the bridge the width increases to upward of 2,000 feet.

The high-water width of the river is about 4,000 feet. The left bank is high and rocky. An attempt was made, between the years 1853 and 1857, to confine the river at Dubuque between its low-water banks, in all stages, by building a levee along the right bank from a point just above the site of the bridge to the lower end of the city of Dubuque. Some of the streets of the city were extended out to it and through these streets small openings were left to allow for the drainage of the city and bottom land. Through the low land thus leveed ran the outlet of Lake Peosta. This lake is of considerable extent even at low water. It receives the drainage of a considerable section, and at times of high water becomes a part of the Mississippi itself; the water coming into it over the low bottom land between it and Eagle Bluff 3 miles above the site of the bridge. There is a saw-mill located on this lake, the logs for which are brought in from above at time of high water. The openings left in the street extensions were too small to carry off the water brought in through this lake, and a portion of the levee was carried away below, and another opening made above Seventh street extension, at the first high water succeeding the completion of these improvements. This latter opening, called Seventh Street Slough, is considerably used by the lumbermen to lay up lumber rafts until they are ready to haul out the lumber. The works of embankment in Dubuque greatly contract the natural water-way at high water at the site where the bridge was afterward built, and consequently at this stage the flood-water pouring into the narrowed water-course from the right side above the bridge, produces a marked change in the course of the current of the main stream from what it is in ordinary and low stages. No attempt has since been made to repair the levee or close the openings in the dikes, and this would be impracticable unless the work of leveeing were carried up to Eagle Bluff, excluding the river water from Lake Peosta.

SURVEYS.

A survey of about 4 miles of river in this vicinity was made by us in September, 1866. The location of the bridge had not been fixed, so no special examinations were made at any particular locality. This survey showed that the river had a good navigable depth, small slope, 0.25 foot to the mile, and consequently slow current, it being in this respect a good point to bridge the river. An examination was made in 1868 at time of low water when the bridge was nearly completed, and another in 1869 when the water was high. The rise from low to high water at this place is 22 feet.

DESCRIPTION OF BRIDGE.

(See Diagram 16.)

Approaches and arrangement of spans.—The bridge approach from the Iowa side is over bottom land or trestling, for a distance of 2,400 feet; a portion of this distance is on a curve of about 1,400 feet radius. The first pier is placed upon the old levee at a point 125 feet back from the usual low-water shore line. The next pier was built in the river at what at the time of our examination was a dry sand-bar, the river being 3½ feet above extreme low water. The other piers stand in the water. The spans commencing at the Iowa shore are, first, four of 225 feet from centers; then one of 250 feet from centers; then a draw-span, 360 feet

over all, with clear openings of 160 feet; then a span of 250 feet reaching to the Illinois abutment. One hundred and fifty feet from this abutment is the entrance to a tunnel 835 feet in length. This tunnel is 22 feet wide, 18 feet high, and is on a curve of about 625 feet radius. This bridge takes up only so much of the water-way as is occupied by the piers, the full width being allowed for the passage of flood-waters.

Substructure.—The masonry of the piers rests upon grillages placed upon piles which are sawed off about 10 feet below low water, where the water was deep enough. The dimensions of pier No. 4 (see Diagram A'), counting from the one on Dubuque levee, are as follows: 24 feet long on the bridge-seat, and 7 feet wide, with a batter of one-half inch to the foot vertical. At a point about 12 feet below the bridge-seat there is a band course projecting 4 inches; below this course the upper end is finished as a starling, with a slope of 4 inches to the foot on the nose. The horizontal sections of these starlings are equilateral triangles with the exposed sides hammer-dressed. The lower end of the pier below the band course has a semicircular horizontal section. Above the band course both ends are finished as sections of cones running about half way up to the bridge-seat. The bottom of the masonry in deep water is about 10 feet below extreme low water. At this level the pier is about 50 feet long and 12 feet wide.

Riprap was placed about all of the piles to an extent deemed sufficient to protect them against scour. The draw rests are timber cribs built above high water, with compartments filled with riprap. These cribs were placed upon the bottom of the river and protected by riprap. At the next high water, sand scoured out beneath and let the riprap down, and when the water fell the sand was deposited over the riprap. Additional stone was put in of 1½ cubic yards in size.

Superstructure.—The superstructure is of iron, built by the Keystone Bridge Company, of Pittsburgh, Pa. All the parts of the draw are of wrought iron; in the other spans cast iron is used for the upper chord and the head and foot of the posts. The draw is opened and closed by a small engine resting upon the drum of the turn-table; it is also provided with apparatus for turning by hand. The engine drives a horizontal shaft, geared to a vertical shaft that turns the draw by cogs around the perimeter of the drum. In attempting to open this draw-span in a high wind the engine proved of too little power to control it. In its course it struck the plates on the rest-piers and tore them off, and displaced part of the coping of the piers. The engineer attempted to stop the draw by reversing the motion of the vertical shaft, but it was torn from its fastenings to the drum. This occurred in the first year after the bridge was opened. It was then proposed to replace this engine with one of more power, but I do not know what has been done.

INFLUENCE UPON NAVIGATION.

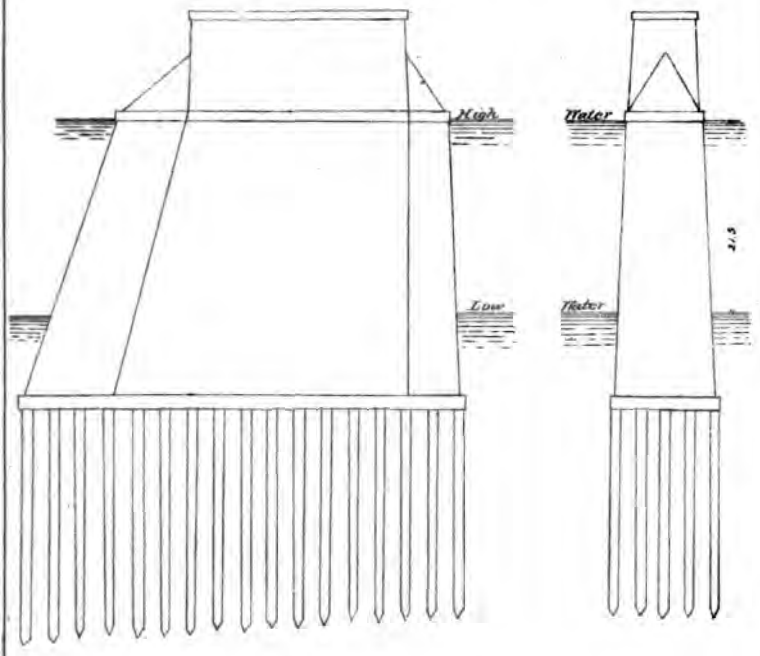
Our examination of this bridge in November, 1868, was when the water was 3.7 feet above extreme low water, and its maximum velocity about 2 miles per hour. The general direction of the current through the east draw-opening was nearly parallel with the axis of the piers. In the first span to the right of the draw the currents set toward the right at an angle of about 10° with the axes of the piers. This span is generally used by rafts. At the time of our examination in 1869 the water was 13.2 feet above extreme low water. The maximum velocity was through the draw-spans, and was about 3 miles per hour. The general direction of the current through the east draw-opening, at that time,

Dubuque, Iowa.

ELEVATIONS OF PIER 4.

Scale of Feet

0 10 20 30



AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS.)

made an angle of about 5° with the axes of the piers. Through the west draw-opening the general direction taken by floats was nearly parallel with the axes of the piers. The change in direction between low water at the time our first observations were made, and at high water when our second observations were made, was considerable. But at each stage one of the draw-openings was available, with current direct through it. At low water the left draw-opening was the better, and at high water the right opening was the easier to run. From the right bank, at time of high water, the current sets toward the center of the bridge, so that floats put in opposite the span next Dubuque, 1,000 to 1,500 feet above the bridge, passed through the fourth span from the Iowa shore at an angle of 25° with the axes of the piers. This was caused by the current setting out of Seventh street slough immediately above the bridge. The current through the long span next to the right draw-opening was practically parallel with the axes of the piers. The span next the draw on the left or Illinois side cannot be used for rafts floating with the current on account of a bank built out, and formerly used as a transfer landing, about 400 feet above the bridge. If, from this point, a line be drawn in the direction of the current (nearly parallel with the piers) it will cut off 150 feet of this span, and this is practically equivalent to reducing the width for raft navigation by that amount, which renders the whole useless. This span, if its full width had been made available to rafts, would have been very useful.

The passage-way provided for steamboats is as good as a draw-bridge at the site permits, unless by proper rectification of the Illinois shore it had been made so that one draw-opening could be placed next to it. This would have been especially desirable at this point, which is one where the wind is very troublesome to boats passing the bridge. It would have brought the 250-feet span, which is on the right of the draw-opening, 100 feet nearer the center of the stream, and rendered its use by rafts more easy.

ALTERATIONS TO LESSEN OBSTRUCTIONS TO NAVIGATION.

Sheer-booms.—The board of engineers recommended that a sheer-boom 1,200 feet long be placed with its lower end abutting against the pier on the right of the Iowa 250-feet span, and to extend up stream on prolongation of the axis of the pier, so that it can be swung to sheer rafts into the right raft span, or into the right draw-span. Those representing the raft interest before this board asked for booms on other piers, but as they would interfere with the passage of the bridge by steamboats, they were not recommended.

Lengthening of left rest pier.—This pier should be extended up stream 800 feet in the direction of the current. This extension should be 4 feet above high water, and built of timber with its sides smoothly planked. If this were built boats could "round to" and drop through the bridge alongside of it avoiding the now frequent delays on account of darkness or high winds.

HIGH BRIDGE.

This place is one of the most favorable for a high bridge on this part of the river. The left bank is high close to the shore, and high land opposite is but one mile distant. The provisions for clear headway of 55 feet above high water, which is 77 feet above low water, would give an opportunity for all boats to pass under it that can pass the bridge at Saint Louis. (See Chap. III.)

PROPOSED PONTON BRIDGE AT DUBUQUE, IOWA.

An act of Congress approved March 3, 1875, authorized the construction of a pile and ponton bridge across the Mississippi River at or near the city of Dubuque, Iowa. The proposed plan and location were submitted to the Secretary of War. A board of engineers—Col. J. N. Macomb, president—was convened to consider and report upon them. This board objected to the first and second locations, which were near the present bridge, but approved of the third, which was at Eagle Bluff, 2½ miles above. (See Annual Report of the Chief of Engineers for 1876, Part II, pp. 308, 313.)

This bridge has not been built.

CLINTON RAILWAY DRAW-BRIDGE.

(Opened for railway travel in January, 1865.)

Authority.—This bridge was built by the Albany Bridge Company under authority of the legislatures of the States of Illinois and Iowa. The portion over the east channel and Little Rock Island was built and in operation some time previous to the building of that portion over the west channel, the transfer over this being made by ferry. It was declared a post-route by act of Congress approved February 27, 1867.

DESCRIPTION OF RIVER AND VALLEY AT THE LOCALITY.

(See Diagram 17.)

In connection with this bridge we shall consider the question of a high bridge at Fulton and Lyons, about 2½ miles up the river, and our description will therefore embrace that locality.

The high ground at Fulton, on the Illinois side, extends only about a mile along the river. The river here is about 3,500 feet wide, and all confined to one channel. About one mile below the high ground the bank of the Illinois side or left bank is composed of a low stratum of lime-rock for a short distance, and opposite this the river at low water is reduced to a width of 2,400 feet, part of which is occupied by a dry sand-bar. This place is about a mile above the bridge, and on many accounts presents a good site for a bridge (although the banks are not above overflow) because the deep water is constantly next the rocky shore. At the site of the bridge the water-way is divided by Little Rock Island. The main channel is on the right or Iowa side of this island, and does not change. The island is composed of stratified lime-rock, a little elevated above ordinary overflow. Between the island and the left bank the water-way is shoal and much of it occupied at low water with dry sand-bars and willow-islands. The main bank on the Illinois side is alluvial, and subject to overflow. On the Iowa side it is rock in place, but not above extreme high water.

Little Rock Island is in the jurisdiction of the State of Illinois, the middle of the west channel being the dividing line between the States of Illinois and Iowa.

The width of the valley submerged at high water is about 2 miles. The slope of the water is about 0.27 feet per mile at low water. The current is gentle, being 1¾ miles per hour when the water is 2.5 feet above low water. With the water 10.7 feet above low water it is about 3 miles per hour in the main or Iowa channel. The rise from low to high water is about 19 feet.

SURVEYS MADE.

A survey of the Mississippi at this bridge was made by me in October, 1866, at a time of ordinary low water, and all the information that could be obtained at this stage of water was secured. Both banks were meandered from Fulton and Lyons down about one mile below Clinton, the river sounded, and current observations taken at the bridge. Current observations were again made here in May, 1867, at time of high water, and again in November, 1868, when the water was low, at the time of the rebuilding of that portion over the east channel.

DESCRIPTION OF BRIDGE.

(See Diagram 18.)

Commencing on the left or Illinois shore, there is 1,390 feet of wooden trestling in the approach to the bank of the river; then there were at first 7 spans of wooden trusses, each 200 feet long; then a causeway 583 feet long across Little Rock Island to the Iowa channel. The Illinois channel thus bridged was crossed at an angle of 74° with the general direction of the channel, so that these spans of 200 feet from centers were practically narrowed to about 190 feet, measured at right angles to the current, and this was decreased by the width of piers and protection of riprap to 160 feet. The riprap protection was raised to about 3 feet above low water; the available width above this stage was practically about 180 feet. The span next to the Illinois shore, the one used by rafts, had this width available for all stages above 3 feet above low water. The headway at time of high water was about 8 feet under these spans. At the time of our survey, in 1866, this bridge was in very bad condition, the piers, built with a core of concrete, were cracked in several places, and to support the spans temporarily various devices had been resorted to. The trusses, which were of that pattern known as McCallum's, were decayed in many parts, and a large number of the diagonals were split and broomed where they abutted against the angle blocks.

In 1868 and 1869 this part of the bridge was entirely rebuilt; the first span next to the Illinois shore was replaced by an iron truss; the remaining portion, 1,200 feet to the abutment on Little Rock Island, was replaced by 8 iron spans of 150 feet each; the new piers were smaller, 9 feet wide on top, of masonry, resting upon piles. The 200 feet span and the two adjoining 150 feet spans were built by the American Bridge Company, of Chicago, on the Post pattern. The next two spans were built by the Detroit Bridge Company, Detroit, Mich.; the next two, by the Phœnixville Bridge Company, of Phœnixville, Pa.; the next two, by the Keystone Bridge Company, of Pittsburgh, Pa. The last six are of the Pratt truss pattern.

The bridge over the Iowa channel, built in 1864–'65, consists (commencing at Little Rock Island) of one span 174 feet and 200 feet of wood; then a pivot draw-span of iron (Bollman) 300 feet over all, with an opening on the east side of pivot-pier of 119 feet at low water, and one of 128 feet on the west side; then a span of 174 feet to abutment on the Iowa shore (this is of wood); then a short piece of embankment.

Substructure.—The piers in the east channel, before referred to, are of masonry, resting on a grillage which rests upon piles sawed off below low water. The pivot-pier and guard-rests are combined in one large crib about 400 feet long and 35 feet wide. The left rest-pier is also a crib filled with stone, 140 feet long and 25 feet wide. The excess in width

of these cribs over what would be proper masonry piers is taken from the clear openings of the draw-span. The right rest-pier is of masonry; this opening is 128 feet, while the left opening is but 119 feet. The lowest part of the draw-span is 66 feet above high water. The draw is turned by an engine placed on the truss above the roadway. This was the first draw on the river turned by steam-power.

INFLUENCE UPON NAVIGATION.

Steamboats.—From the time of the opening of navigation, March, 1865, considerable delays were experienced by inability to pass it in time of high winds and dark nights. Vessels were compelled to wait during the prevalence of a high wind sometimes as long as two days at a time. Damages to considerable extent were suffered in passing the bridge, and, in consequence of these and the injurious delays, suits were instituted or threatened against the bridge company.

The effect of this bridge upon navigation is stated in my letter to the chairman of the Senate Committee on Post-Offices and Post-Roads, dated February 5, 1867, which appears in Chapter V of this report. The subsequent examination made at high water showed that the direction of the current was not essentially different from that at low water, but that the eddy above the bridge near the west shore was much larger and stronger in high water, making the approach to and passage through the draw-opening more difficult.

Several steam saw-mills have been erected on the right bank below the bridge, which, like all mills or furnaces, make at times dense smoke and bright lights, that greatly interfere with the safe navigation of the river in their vicinity, and add to the difficulties in the passage of the bridge.

The difficulties which steamboats encounter in passing this bridge, appertaining especially to it, may be summed up as follows: the narrow draw-opening, 119 feet in the clear; the eddy above the bridge, which makes the course of the current to continually change, and the curve in the main channel where the bridge crosses. These are sufficient to prevent steamboats passing in time of high winds, to which this part of the river is very liable, and in dark nights and thick weather, the effect of which is intensified by the mills located near it.

Rafts.—This bridge is now a greater obstruction to the passage of rafts than it was at the time it was legalized in 1867, because of the change which has taken place in the method of rafting. Formerly the rafts were all managed by men using large sweeps, and the passing under the low bridge across the Illinois channel did not interfere with the control of the raft, but now the larger number of the rafts are managed by means of small steamboats, and they cannot pass under the bridge. The raft has to be dropped near the bridge in the Illinois channel, and the steamboat goes around the head of the island and passes through the draw-opening in the bridge over the Iowa channel. The bridge over this channel does not furnish suitable openings for the passage of rafts in its present state, though near low water the rafts are sometimes separated into smaller parts and dropped through this channel by the boats.

The spaces between the piers of the bridge over the Illinois channel are not sufficient for rafts, for which this is the usual channel.

The difficulties attending the passage of this bridge by rafts are set forth in detail in the report of the board of engineers on sheer-booms, dated Saint Louis, Mo., February 2, 1877. (See Annual Report Chief of *Engineers* for 1877, vol. 1, p. 817.)

ALTERATIONS TO LESSEN OBSTRUCTIONS TO NAVIGATION.

Although it is probable that an entirely new and different bridge will be required to meet the wants of navigation if the principle is to be carried out which was enunciated in the report of the House committee in 1858, of which the Hon. E. B. Washburne was chairman, "that any bridge is a *material obstruction* which is susceptible of being essentially improved," still there are a number of changes that can be made in the present structure that will make it less of an injury to navigation than it now is.

Sheer-booms.—The board of engineers upon sheer-booms, to facilitate the passage of rafts, recommended that a fender be built along the bank above the bridge over the Illinois channel to prevent rafts being drawn into the timber on the bottom at time of high water; that a fixed boom be placed from the upper end of the pivot-rest in prolongation of its east side to the shore above, and that another fixed boom be placed from head of the pier east of the first span east of draw to the head of Little Rock Island. These booms are to be so constructed as not to interfere with steamboat navigation, and it was thought that the boom running from the upper end of the draw-rest to the Iowa shore would facilitate the passage of the bridge by boats.

Straightening the channel.—A further improvement, and one particularly desirable in the present arrangement of the draw-spans, would be cutting off the point of rock above the bridge on the west bank, and filling out the hollow of the bend below so as to destroy the eddy that now makes the passage of the draw difficult. To cut off about 170 feet of the point down to 6 feet depth at low water, requires the removal of about 32,000 cubic yards of rock. The material excavated could be used in making a new bank in the bend below in prolongation of the west rest-pier. This it is believed would make the west draw-opening available when the obstructions placed below it by mill-owners and others are removed, and make unnecessary the sheer-boom to the Iowa shore recommended by the board of engineers.

Rebuilding east rest-pier.—This could be done by removing it down to 6 feet below low water, and replacing it by a stone pier of the usual dimensions, which would add about 10 feet to the width of the east draw-opening. This could be done without interrupting travel over the bridge, and without great expense.

Building new draw with wider openings.—A much greater improvement would be to remove the present draw and the fixed span next east of it, and replace them by a draw having openings of 160 feet in the clear, the same width as has been required in the other bridges on this part of the river, and put a fixed span over the present west draw-opening. To do this would require building a new pivot-pier east of and alongside of the east rest-pier, and a new east rest-pier. This can be done without interrupting navigation, and with but little interruption to the travel over the bridge. This change would make this bridge as good for navigation as any draw-bridge on the river, and would do away with the necessity for the previously suggested changes.

As all of the spans over the Iowa channel, except the draw, are of wood, they must soon be rebuilt; and the piers also are of such nature as to require rebuilding before many years.

HIGH BRIDGE.

At this place a continuous bridge should be about 58 feet above high water, or 77 feet above low water, the natural location for which is at Fulton or Lyons.

PROPOSED BRIDGE AT CLINTON, IOWA.

The act approved April 1, 1872, authorized the Chicago and Quincy Railroad Company to build a bridge at this place, and provided in section 4 that it should be available to all railroads desiring to use it, on such terms and conditions as might be prescribed by the Secretary of War. *Section* 5 made the control of the Secretary of War over this bridge greater than had been defined in any previous act, and defined the reserved authority of Congress in compelling future modifications, if required by the interest of navigation.

The act of Congress approved June 4, 1872, made these requirements applicable to all bridges to be constructed thereafter across the Mississippi River under any act of Congress. These provisions are copied in full in this report in giving an account of the bridge at La Crosse, Wis.

Section 4 of the act approved June 6, 1874, provided that the bridge authorized to be erected across the Mississippi River at the town of Clinton, Iowa, by act approved April 1, 1872, "may be constructed and maintained as a pile and ponton bridge," and on September 29, 1874, the Mississippi Union Bridge Company submitted the plan to the Secretary of War. The Chief of Engineers, on being directed to report upon it, submitted the matter to a Board of Engineers of which Col. J. N. Macomb was president. The Board reported on the 8th of October, 1874. (See Annual Report of the Chief of Engineers for 1875, Part II, pp. 682–684.)

The Board recommended some minor modifications in the proposed bridge, but it has not yet been built.

THE NEW ROCK ISLAND BRIDGE.

(Tested May 8, 1872; opened for railroad travel October 8, 1872.)

This bridge, built by the United States (partly at the expense of the railroad company), presents an anomalous case, and, as far as it is a precedent, deserves more notice in this report than any other. Its location and general design were controlled by a number of important requirements, all of which were known, and being built under officers of the government, there is no consideration which influences the present form of this structure that may not be fully and positively stated. Such is not the case with bridges built by private corporations, where it is impossible to know what relative value was given to considerations of a public and general or of a private and local nature. We will therefore begin with an account of the first steps towards its construction.

PRELIMINARY STEPS.

The old bridge having been shown to be a serious and unnecessary obstruction to navigation, Congress, by act approved June 27, 1866, to establish an arsenal, &c., authorized the preliminary steps to building a new bridge and removing the old one. The questions with regard to the change of the railroad were referred by instructions from the Chief of Ordnance (General Alexander B. Dyer), September 21, 1866, to the commissioners appointed under the acts of April 14, 1864, and June 27, 1866, whose duty was to ascertain the true value of the lands and property rightfully owned by those who would have to be dispossessed in adapting the island to the use of an arsenal. This commission was directed, after hearing the parties in interest and taking the necessary testimony—

To suggest the proper change in the location of the railroad and bridge, and the kind of wagon-road that should be established, and the kind of aid that should fairly

and equitably be granted toward effecting these objects. * * * It is essential that the new location of the railroad should be made on the lower end of the island, as laid down on a plat to be furnished by the commanding officer of Rock Island Arsenal (General T. J. Rodman).

The location, as thus laid down, was nearly that on which the new bridge was built, and its adaptability to the wants of the railroad company indicates that their views were consulted in making it. It was arranged for two spans 375 feet each from end to end over the main channel, with bottom chord 50 feet above high water. The rise from low water to high water was set down as 16 feet, so the gorge high water about 5 feet higher, occurring sometimes at the breaking up of the ice, was not considered. The trusses each side were to be deck trusses, and provided for an inclination of the rails in reaching the higher spans. Alongside the trusses making the railroad approaches to the high spans were other trusses for the wagon-way, allowing of more inclination for the highway than for the railway, but both roadways crossed the high spans on the same grade. This commission consisted of Maj. Gen. J. M. Schofield, Mr. (General) James Barnes, Mr. Selden, and Mr. Church. Their report to the Chief of Ordnance is dated February 4, 1867. It was forwarded by the Chief of Ordnance with recommendations and suggestions February 8, 1867, and is printed as Sen. Ex. Doc. No. 27, Thirty-ninth Congress, second session. During the investigations of the commission, they obtained from Mr. E. H. Johnson, the chief engineer of the Chicago, Rock Island and Pacific Railroad, an estimate of the cost of such a bridge as General Rodman proposed, with the substitution of high spans of 250 feet from centers of piers, instead of 375 feet (the wagon-way to be 17 feet wide and the railroad to have a single track), to cost $1,671,241.81. The commission also obtained an estimate of the cost of a low draw-bridge with the wagon-road above the other, with the provisions regarding the position of piers in the direction of the current, and the position and dimension of spans, provided for in the law for the Quincy bridge. The total cost of this was estimated at $1,296,292.11, and of this sum $1,046,317.58 was for the part over the main river, connecting Rock Island with Davenport. (See Annual Report Chief of Engineers of 1869, pp. 194–199.) The railroad company submitted a proposition setting forth the share of the expense it would take in making the change. When this proposition was afterward considered by the commission, the ordnance officers objected to the width of the wagon-way proposed, which was only 17 feet; and it was thought a much wider wagon-way was necessary, say 26 feet. The railroad company then suggested that the increased width would admit of the railroad being a double track. When this point was reached, the estimates were sent for revision to Mr. Johnson, who thought there was no reason to change his first estimate of cost. It is surprising that such a view should have been entertained. I came in charge in 1869 and made an estimate of the cost of the enlarged bridge, allowing the same prices, and found it would be $1,785,142.67 from Rock Island to Davenport, and including the bridge between the island and Illinois $2,121,526.82. (See Annual Report Chief of Engineers for 1869, pp. 194–199.) Without referring to cost, however, the commission recommended the proposition of the Chicago, Rock Island and Pacific Railroad Company (their assent to the foregoing modification for a wide roadway being duly certified to.)

The essential features in the question of bridging as agreed upon are as follows:

The government to build over the main channel of the river an iron draw-bridge in accordance with the conditions prescribed in the act of Congress of July 25, 1866, the

frame to be of proper breadth for a double track; the wagon-way to be placed high enough to leave the lower chord for a railroad track; the government to give the company the right of way across this bridge and across the island upon the payment of half the cost of superstructure.

The Chief of Ordnance, in making his report to the Secretary of War, submitting the report and recommendations of the commission, said:

If the bridge is to be built by the government as recommended by the commission, an additional appropriation of $1,000,000 is requested, and it is desirable that it shall be made before the end of the present session.

The words "additional appropriation" undoubtedly referred to an appropriation in addition to estimates previously submitted. It could in no way be regarded as a statement of the estimated final cost of the bridge, as it was afterwards mistaken to be, the mistake causing a serious obstacle eventually to getting to work on the bridge.

In the act for the support of the Army, approved March 2, 1867, $200,000 was appropriated towards building the new bridge, according to the recommendation of the Chief of Ordnance. This recommendation was, more properly speaking, that of the commission. The Chief of Ordnance somewhat qualified his approval, and thought the proposal liberal on the part of the United States, and too much so if the railroad company had not already a right of way. The act required, however, the execution of certain papers binding the railroad company to certain conditions, in regard to future preservation and repair, ownership, use, &c., which the company was found unwilling to accede to, and as the act was not compulsory the commencement of the bridge was stopped.

The Chief of Ordnance says in his report dated October 19, 1867:

As it is doubtful whether the guarantee which the company is willing to give would fulfill the requirements exacted by Congress of the company in making the appropriation, I would respectfully recommend that the subject be brought to the notice of Congress for such action as may be considered necessary and proper.

A joint resolution was framed to meet the case and was approved July 20, 1868, which gave specific authority to the Secretary of War to allow sixty days after its passage for the railroad company to file an agreement in accordance with it, and if not filed then, he should direct the removal of the existing bridge and proceed with constructing the new one, which the railroad company should not have the use of until it had agreed to and complied with the provisions required of them. This joint resolution contained a proviso that "in no case shall the expenditure on the part of the United States exceed $1,000,000." At the end of section 2 are the words, "all acts or parts of acts inconsistent with these resolutions are hereby repealed." In the complications which followed a due regard was not had to this repeal of parts of former acts inconsistent with this proviso, limiting the cost to $1,000,000.

The act making appropriation for the support of the Army, approved March 3, 1869, appropriated $500,000 towards building the bridge.

The agreement between the United States and the railroad company was signed by General J. M. Schofield (then Acting Secretary of War), and John F. Tracy, president of the company. It has no date, but it was not many days prior to September 10, for on that day the Chief of Ordnance requested authority to commence the work (the agreement as he states having already been signed) and to authorize the employment of a competent civil engineer to aid in the work.

A marked feature in the agreement signed is the following:

Provided that the aggregate cost of said bridge shall not exceed $1,276,292.11, the estimate of the same made by the commissioners appointed under the act approved June 27, 1866.

There is no record that the commission made such an estimate, but (as I found on coming in charge of the work in July, 1869) Mr. Johnson, engineer of the railroad company, did make such an estimate, which was for a wagon-road 17 feet wide and a single-track railway. This project was not recommended by the commission nor by the Chief of Ordnance, but a modification of it requiring a wider wagon-way and double-track railway, and this double-track railway and highway could by no possibility have been built for the amount specified in this agreement. It is singular that this discrepancy was not discovered and prevented while the agreement was being negotiated.

It happened fortunately, however, that the amount specified in this agreement is very nearly in accordance with the limiting cost of $1,000,000 for the part over the main river as made in the joint resolution, and *if the repealing proviso of this resolution had been regarded, the previous enactment that the bridge should be built as recommended by the Chief of Ordnance would have been done away with, and no obstacle would have existed in the further prosecution of the work on the best plan with the limit of cost which the joint resolution made.* The commanding officer at Rock Island, General Rodman, having been directed on March 29, 1869, to advertise for proposals for constructing the piers of the bridge, was confronted at once with the question as to what kind of a bridge to build according to the laws, and endeavored to frame his specification so as to meet contingencies that might arise in the settlement of this question. On May 26, 1869, he addressed a communication to the Chief of Ordnance, presenting the whole subject, stating that if the limitation of cost to $1,000,000 in the joint resolution was to include the reimbursements for the cost of half the superstructure, then it was impossible to build the bridge recommended by the commission, nor did he deem it advisable to build such a bridge. He then submitted a plan for a single-track railway with the wagon-way above it, and another for a single-track railway with the wagon-way below it; the latter he stated being not only cheaper, but much more sightly "and incomparably more convenient in itself." He further stated that as the agreements with the railroad company contemplated the wagon-way above, the change would somewhat increase the cost of their approaches, and it would be just to allow them the difference in making the proposed change, and that the company had expressed itself willing to make such agreement. There seems to be no good reason why this should not have been the first plan recommended, and I think it was lawful even at this time.

A contract for Utica hydraulic cement was made on May 31 with James Clark & Son. This contract was for all the cement required at the arsenal as well as the bridge. A contract for Joliet stone for the bridge was made with Sawyer & Talcott May 15, 1869. A contract for the masonry (a source of great trouble afterwards) was made with Harvey & Livesy June 1, 1869.

General Rodman's plans all contemplated the completion of the piers in the season of 1869. The questions raised by General Rodman as to plan of bridge and cost were referred to Judge-Advocate-General Holt, who gave as an opinion, in a letter dated July 4, 1869, that the plan of this bridge, originally recommended by the Chief of Ordnance as named in the act of March 2, 1867, could not be departed from, nor could the provision that the cost, limited in the subsequent joint resolution to $1,000,000, be made to mean that amount exclusive of the amount reimbursed by the railway company. The Attorney-General approved the view of the Judge-Advocate-General.

The first-provided bridge would cost double the limit, and under this interpretation the first act was found defeating a subsequent act completely, which had provided "that all former acts inconsistent with it are hereby repealed." The Judge-Advocate-General's opinion makes no allusion to this repealing clause, which effectually did away with former recommendation as to kind of bridge.

A dead-lock was then put upon further proceedings in building the bridge.

The Adjutant-General of the Army, in transmitting to General Rodman the decision of the Attorney-General June 10, 1867, said: "If it is impracticable to construct the prescribed bridge for the sum named, immediate report of it will be made to the Secretary." The substance of this was telegraphed June 10, and on July 11 General Rodman answered by telegraph that it was impracticable. On June 15 General Rodman urged that the clear intention of the law was to build a bridge, and he did not think that any plan could have been intentionally prescribed that would have prevented the main object. He did not, however, refer to the repealing clause in the joint resolution. He was again written to on June 18 by the Chief of Ordnance that the decision could not be changed, but to suspend work till he could reach Rock Island, a week thence.

On June 28 the Chief of Ordnance telegraphed from Rock Island:

Railroad can be built for sum fixed by Congress as to limit, wide enough for double track and strong enough for one train, leaving question of relative position for future determination. The work can be commenced at once. Shall I authorize General Rodman to commence building piers? I recommend it. Railroad company will agree that railroad-track shall run above wagon-road.

On June 29 the Secretary of War telegraphed

To commence at once. The bridge to be in exact accordance with the recommendations of the commissioners, and not to exceed the limit of cost of $1,000,000.

On June 30 General Rodman informed the Chief of Ordnance that he would proceed at once to construct the piers wide enough for a double track.

WORK TRANSFERRED TO THE ENGINEER DEPARTMENT.

On July 9, 1869, the Secretary of War (Hon. John A. Rawlins) transferred the construction of the bridge from the Ordnance to the Engineer Corps, and on July 10 the Chief of Engineers (General A. A. Humphreys) assigned the duty to me (G. K. Warren, engineers). Dispatches on this day were sent to me at Saint Paul, Minn., to which place I was returning from several months' duty as commissioner on the Pacific Railroad, which dispatches I received on my arrival there on the evening of the 13th. On the 14th I telegraphed General Rodman as to the necessity of my immediate presence, and gave my efforts to closing up the business that had accumulated at Saint Paul during my long absence, and to giving directions as to the future. On the 17th General Rodman's dispatch said I had better come at once, so I sent Major Stickney down to represent me. On the 20th I submitted a plan for a railway draw-bridge (made from a section I had sounded in October, 1866, and at which place I measured the velocities), based on the report of Mr. Clarke, engineer of Quincy bridge, to cost $1,000,000, but I had no knowledge then of the difficulties of the case as heretofore presented, much of which was not obtained until as late as December following. I was, however, getting surveying parties ready to make a new survey at Rock Island, as probably would be required. On the 23d of July I received a telegram to proceed at once myself to Rock Island, which

I did. The instructions to me were, at the first, to stop all work until I was authorized to proceed, but before authority would be given "the Secretary of War must be fully satisfied that the bridge should conform to all the conditions of proper strength and stability, non-obstructing navigation, and cost." Earnest attention was required, and a full report at the earliest practicable time. On July 21 the contractors were all stopped. At this time the contractors for stone had delivered $15,000 worth. The contractors for building the piers had expended about $4,000 handling and cutting stone, and would lose, they claimed, $2,500 per month by being stopped. General Rodman had, under the plan he adopted, located the abutment on the Davenport side, and the contractors were about to go to work upon it.

I reached Rock Island and received the principal documents from General Rodman on July 26. These were sufficient for continuing the work in the manner laid out by him; but this was all suspended, and I had to make a plan from the beginning. There was an absence of thorough soundings of the river-bed and observed courses of current that called for all the provisions I had made in fitting out a surveying party.* This surveying party, under Mr. J. P. Cotton, civil engineer, at once began to measure the current and obtain the soundings, the latter being a very laborious process in the swift current in the stage the river then was, 7 feet above low water.

Maj. Amos Stickney, Corps of Engineers, with an assistant, was assigned to the duty of obtaining information about and preparing for building the piers. Besides the general supervision of the work, I took upon myself the work of obtaining information on the subject of superstructure, and of finding out exactly the conditions under which the work had been transferred to me. It was soon ascertained that there was no estimate of cost made by the commissioners at Rock Island for a double-track railroad and highway, as recommended by the Chief of Ordnance. This estimate was sought for in every place where it could have been placed, without finding it.

After an examination of all there was known of the subject at Rock Island, I found it would be necessary to visit Washington for consultation and to obtain access to important papers relating to the subject that were still there. Authority was given me to do this, and on the 30th of July I sufficiently understood the subject to prepare a plan for beginning work, which was not materially different from that prepared by General Rodman, except that I did not adopt his location of the piers, and required time to make surveys and consider this matter. The delivery and cutting of the stone for the piers, excepting for the starlings, whose form remained a question, was resumed, adopting as the batter for the piers a slope of 1 inch horizontal to 24 inches vertical.

On my return to Rock Island, the survey to get the form of the bed-rock in the river and the courses of the current was pushed with energy and plotted as fast as made. No definite location was advisable until these should be fully ascertained, and thus far they had not been. A survey by a newly-invented sounding arrangement prepared in the office of the Rapid Improvement had been made before, but from want of experience of some sort the map made was worthless.

* Colonel Flagler, in the Annual Report of the Chief of Ordnance for 1877, p. 142, states that "during the year 1869 General Rodman made careful surveys of the bed of the river, measurement of the velocity at different stages of the water," &c. On this point Colonel Flagler is misinformed, for General Rodman made no such surveys. It is due to myself to say this, for the delay I made in submitting a plan was necessary to make such surveys.—G. K. W.

The requirements which the bridge had to fulfill were:

First. Not to cost over $1,000,000 for the part over the main channel.

Second. Not to obstruct navigation.

Third. To accord with the purposes of the United States in the occupation of the island as an arsenal.

Fourth. To meet the wants of the railroad so as to suit its purposes and not necessarily interfere with the streets of Davenport.

Fifth. To have the wagon-road part of the bridge not upon private property.

Sixth. To correspond with the recommendations of the Chief of Ordnance as required in the act of March 2, 1867, to wit, a double-track railway with the wagon-way on top.

Beyond any doubt, the first and last named of these requirements it was impossible to reconcile, and it was thought that if Congress had not already repealed the one last named, it would do so, as all parties interested were in favor of making it a single-track railroad above the wagon-way, because it was better and less expensive. It was decided, therefore, that the piers should be for the least width a double track would require, and not to contract for the superstructure until action by Congress should be taken after a full presentation of the matter at the next session. To meet the requirement for double-track railway, the piers were made longer up and down stream than was necessary for a single-track railway.

The *fifth* of the above named requirements was very difficult under the plan proposed by General Rodman. In this plan the Davenport abutment was located in the corner of a block owned by the railroad company, the whole bridge passing over the street next the river. Whether there might have been trouble on the part of the city and the railroad company or not, in regard to the highway approach, the city government was much dissatisfied with the arrangement. I soon saw, however, that if the city government would consent to raising the grade of Front street about six feet, I could place the abutment at low water, and descend from the wagon-way placed on the bottom chord immediately into the streets at the intersection of Le Claire, Front and Second streets; thus giving an easy approach in every direction, while the part of the bridge to carry the railroad might be made of half the strength, and pass over the street to the abutment as located by General Rodman. The city government passed an ordinance establishing the grade as I requested, and so this difficulty was removed.

The *fourth* requirement gave me comparatively little trouble, as it had been well met in the location made by General Rodman.

When the current observations and soundings had been only made in part, I thought I would have to move the Davenport abutment up stream or the Rock Island one down; but fortunately this was found finally to be unnecessary, and so General Rodman's position for the axis of the bridge was preserved. This line was so chosen as to cross the main river and island and a considerable portion of the slough on a straight line. The Rock Island city end coming at the end of the embankment of the old slough bridge, enabled the new bridge to be easily built without disturbing the running of the trains, while the Davenport end landed on the railroad company's property, so that the right of way was secured to them, and this they had obtained with special view to passing over the streets of Davenport to their main track.

The *third* requirement, "the uses of the island for the purposes of the government," was also secured in this location, as fixed by General Rodman.

The *second* requirement seemed to me the most important of all.

The current-measurements soon showed that the axis of the bridge, as thus determined, was at right angles with the course of the current at the two stages measured, and the form of the bed brought out by our soundings, of which about 8,000 were made and located by triangulation, gave reason to believe the currents would not materially change direction at any stage. As a consequence of this, the piers would be parallel with the current, as required by law, if placed at right angles with the axis of the bridge, and we should thus gain the full practical width for the passage of water through sections whose lengths were equal to the clear spans. My own observation and study had satisfied me that draw-bridges should be so located as to have one draw opening next the shore. On being placed in charge of the work, the steamboat-men were consulted, and the presidents of the two packet companies wrote me letters urging that the pivot-pier should be so placed as to be next the shore. The depth of water on the Davenport side was too little to allow of the draw being placed there without a much more considerable rock-excavation than was needed on the Rock Island side. In addition, the current was more gentle on the Rock Island side and it was quite near the middle of the river, when we consider the landing at Rock Island City on the main land, as well as Davenport. Another important economical feature in the construction, was that the large pivot-pier on the Rock Island side could be built in comparatively shoal water with deep water alongside of it. I therefore decided upon a location of the draw next the island. It may be noted here, that one apparent provision of the law was neglected, which requires the spans next the draw to be 250 feet; but it is evident that the law intended the draw to be at the best place for it, since it accommodates all the steamboats, and the other only rafts, and it is not to be supposed that the draw openings which were so objectionable in the old bridge on account of swift current, should be again built in swift current to meet this secondary provision, if it could be avoided. The use of the draws of several bridges now built on the Mississippi has been impaired by the designers not taking the same views of the case which I did. This location of the draw, however, was objected to by the commanding officer of the arsenal, in a communication dated November 3, 1869 (see Annual Report Chief of Ordnance, 1877), as interfering with the steamboat landing it might be necessary to have on the island just above it, &c. The whole question was argued before the Secretary of War by me April 21, 1870 (see Annual Report of Chief of Engineers for 1870, pp. 229–236), in the interest of navigation. The chief of Ordnance replied that if those interests required the draw-bridge there, he could conduct the affairs of the arsenal so as not to interfere with it, and so it was decided to let my design remain unchanged. I will say here that in all my relations with the ordnance officers, I was treated in the most frank manner, and aided in every way I could expect, although persons friendly to them expressed themselves in the newspapers as hurt at the summary manner in which the building of the bridge had been transferred to another department.

Arrangement of spans.—The limitations of the law as to cost required me to use the most economical plan I could adopt, and not select unusual spans for the main part of the bridge. I therefore made the span on the river side of the draw 260 feet from centers, and divided the remainder into four equal spans of 230 feet each, reaching to the Davenport abutment, situated at low-water line. At a subsequent period, for the use of rafts, I altered the plan so that the one next the Davenport abut-

ment should have a span of 260 feet (in the clear 250 feet), and proportionately reduced the three adjoining ones. It is questionable whether this last change was best, as there has been a disposition in Davenport to obstruct the use of this opening. But for the limit of cost, I would have at first planned for four spans of 295 feet, instead of five spans, between the right rest-pier and the Davenport abutment.

Form of piers (see Diagram B).—The form of the up-stream starling from the first attracted our attention on account of the great power of the floating ice at this locality. The ordinary rise from low to high water is about 16 feet; but sometimes, on the breaking up of the ice below the bridge, a gorge is formed which raises the water to 21 feet above low water. At such time, it may happen that the ice above the bridge is loosened from the banks in large cakes or fields while it is still firm; it then moves down with great force, when the ice-gorge below gives way. I therefore thought it best to carry the inclined upper starling at a slope of 1 to 1, from low water to 21 feet above, which gives the pier a very considerable extension in the direction of the stream. The form of the horizontal section of the starling adopted is that given by two circles whose radius is equal to the width of the pier at the section. These circles are described with the opposite side as centers, so as to be tangent to the sides of section, and intersect at the nose with an angle there of 120°. With the common form of triangle for horizontal section, this angle is only 90°, and the angle with the sides is 45°, instead of tangent as in this case. The nose of the pier is thus formed parts of two oblique cones with circular bases. The lower edges of the stones on each course are thin, and unavoidably so if the nose of the pier is allowed a slope of 1 to 1. Perhaps 3 on 2 would have answered, and it would have been less expensive. It was at first thought to cut the stones with steps in the upper edge, but as the only injurious effect of time and use would be to reduce them to steps, they were cut with smooth surface. The cut-water of the starling was protected by iron plating. The down-stream starling of the piers is a half cone with circular base. The piers were designed to be 36 feet long and 7 feet wide under the coping, exclusive of the starlings up and down stream; but before they were built Congress passed a law allowing the bridge to be for a single-track railway. The length of the piers was shortened 4 feet, and they were built 32 instead of 36 feet long.

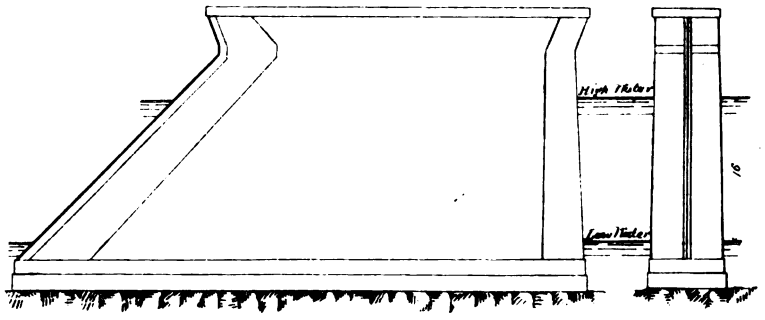
The main draw-pier is built for its special objects, and is of the following description: The center or pivot tier is circular, 36½ feet in diameter under the coping, with a batter of 1 to 24. The upper and lower rests are of masonry; the upper one with a triangular starling with the same slope as the piers, and the lower one a semicircle. The space between the pivot and these rests is a timber crib with apartments filled with riprap. In designing these piers it was sought to take the least possible width from the stream, because all diminution of the natural section resulted in an increase of velocity, the rock bed not admitting of any enlargement of section by scouring between the piers. The area of the natural high-water section (not that of the ice-gorge high-water) was 35,800 square feet. The abutments diminish the width by about 90 feet and the sectional area by 175 square feet, but this is nearly all taken out of slack-water along the shore and does not materially affect the mean velocity. The piers occupy about 1,928 square feet, which is about .056 of the available section for flowage, and they consequently increase the mean velocity above that in the natural section by about .059 of the mean of the natural section. The draw openings, however, are in a part of the river where the velocity is moderate even at high stages.

Rock Island, Ill.
New Bridge.

ELEVATIONS OF PIER 3.

Scale of Feet.

0 10 20 30



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During the progress of forming the present plan of bridge I engaged Mr. George C. Herthel, of Saint Louis, to aid me in calculations concerning superstructure, and Mr. Jacob Blickensderfer in regard to questions of strength of piers, abutments, &c. The position of the piers had been so far determined by the 23d of August that the contractors were informed that they could at once proceed with the Davenport abutment and contiguous pier. The water was then 6 feet above low water. They, however, did nothing at these points, and September 13 they stated they were ready to go to work as soon as the government made the coffer-dams, pumped them out, &c. On the 14th they were informed that this work was included in their contract. On the 15th they filed a protest under which they were willing to work, claiming special compensation for the coffer-dams, &c. The same day, to prevent any further delay, I consented to their going to work, they neither waiving any claim they had rightfully nor I admitting anything they claimed. This action on my part was duly reported and approved. They began work on the coffer-dam September 16. This first trial showed their appliances to be very inefficient. The river had again begun to rise.

By the 20th of September I had everything arranged for the continuous work on the piers, and made my annual report, which recites some of what I have given here and enlarges upon matters not here presented. (See Annual Report of Chief of the Engineers for 1869, pp. 194–198.)

On September 22 I assigned Bvt. Maj. W. H. H. Benyaurd, Corps of Engineers, who had been ordered to report to me for duty, to the task of looking up the whole subject of superstructure by visiting the different bridge-builders and their works, and to collect data needed for a special report to secure the change in the law deemed necessary under present interpretation of existing ones. I then proceeded to give personal directions in regard to some of my other works, and to make a final examination of the Wisconsin River in company with Mr. Jacob Blickensderfer, whose services I had obtained for that purpose. As soon as I had finished the provisional location of a canal along the banks I returned to Saint Paul and worked up the estimates of quantities and cost. When this was finished Major Benyaurd had procured the information he was sent for, and I took it up and wrote another report about the Rock Island bridge, dated December 3, 1869. This is printed in the Annual Report of Chief of Engineers for 1870, pp. 240–246. Here the argument is fully given to show that the repealing clause of the joint resolution of March 2, 1867, did away with the recommendation of the Chief of Ordnance provided in the act of March 2, 1866, and that the Secretary of War could build a single-track railway above the wagon-way without any further legislation, if the cost was kept within the limit provided in the joint resolution. All the engineering data were, however, given in this report. The matter was referred to Congress, and it passed a joint resolution authorizing the bridge as a single-track railway, with wagon-way underneath, as recommended. All obstacles to an easy and rapid construction of the bridge, if low water favored during the ensuing year, were now removed, except for the inefficient contractors and the unsatisfactory contract for building the masonry. The original proposal of the men was sufficiently informal to have justified its rejection; but it was accepted, and the contract drawn by General Rodman, with the intention of making it binding and explicit. The contractors, however, claimed a different understanding of its terms than was allowed by the officer making it, as already stated, and probably regarded their inefficient prosecution of the work as unavoidable in consequence. A bad feature of the contract was that they were

to be paid for finished work measured in the piers, and this precluded my paying them for cutting and handling the stone at a pro rata valuation, which it would have been safe for the United States to do. I could not obtain authority to depart from the strict letter of the contract, and so they were embarrassed for want of payment for work done. The season of 1869 was the most remarkable for continuous high water of any on record, and very unfavorable to this work. Work was resumed in the spring of 1870 on the Rock Island abutment, but high water prevented work on any of the piers. On May 16 I issued the specifications for superstructure which had been prepared, and advertised for proposals for building it. I turned over the work to Col. J. N. Macomb on May 30, 1870. Subsequently I reported on the proposals and concurred in the award that was given of the work to the Baltimore Bridge Company. Colonel Macomb retained Major Stickney in charge of the substructure and Major Benyaurd in charge of the superstructure. The contractors made so little progress in the construction of the masonry that the work was taken from them and completed by hired labor under the officers in charge.

I believe there was no material modification of the plan made by me. The passage-way between the pivot-pier and the island was deepened, but the intention I had to smooth the Rock Island shore and protect boats by means of fenders was not carried out. The part of the bridge over the slough and the causeways across the island, and the approaches in Davenport, were built by the railroad company. The whole was finished and opened to the public October, 1872.

GENERAL DESCRIPTION OF THE LOCALITY AND BRIDGE.

(See Diagram 19.)

This bridge is situated at the foot of Rock Island Rapids (the greater portion of which is above overflow), where the bed of the river is of limestone, the same as above to Le Claire. The width of the river between the Iowa shore and the island of Rock Island is 1,650 feet at the site of the bridge. Immediately below the foot of the island the width of the river increases to 3,000 feet.

The channel on the Illinois side of Rock Island which formerly received a portion of the water of the river, has been for many years closed by a dam, recently rebuilt by the United States Government, so that no water other than what is used to drive the mills at Moline passes through it. The slope of the river above the bridge is 1.7 feet per mile, with a maximum velocity of 4½ miles per hour at the new bridge where the water is 12 feet above low water.

The rocky shores on the rapids for 18 miles above this place, against which a raft cannot land, together with the swift current, makes the running of rafts in this part of the river very difficult. There are but two or three places at which they can tie up, and if these are missed, they must run through the bridge in any wind that may rise while they are passing over this distance.

DESCRIPTION OF THE BRIDGE.

[See Diagram 20.]

The bridge, commencing on the Davenport side, is approached by the railroad on a curve of about 1,200 feet radius from the main track on Fifth street to the junction of Fourth and Rock Island streets, which is

crossed diagonally on a bridge of one span, giving about 12 feet headway to the streets. The approach then continues on the diagonal to the intersection of Third and Iowa streets, which is crossed by a single span of about 120 feet; then it is on a curve of about 1,700 feet radius to the junction of Second and Front streets, which is crossed by a span of 196 feet to the main bridge. There is 12 feet headway above the wagon-road floor. The main bridge has one span of 260 feet, then three of 220 feet, then one of 260.5 feet, and then the draw, 370 feet from end to end, with two clear openings of 160 feet each. A span of 80 feet then carries the railroad-track to the embankment on the island. This embankment extends across the island on a grade of 30 feet to the mile. Then comes a span of 80 feet over the island wagon-way; then the embankment continues 700 feet further to the abutment of the slough bridge. This latter has four spans of 150 feet each, and then there is an embankment on a 4° curve to the main track.

Masonry.—The masonry of the bridge has already been described. The piers in the slough are of masonry, resting on piles. This channel has but little current, it being only the tail-race of the water-power at the head of the island. No special care was observed as to direction in crossing it, or in the obstruction of the water-way.

Superstructure.—The bridge is of wrought iron throughout. The upper chords are of rolled channel-bars, and the lower, open links in the fixed spans. In the draw-span both upper and lower chords are of channel-bars. The draw is opened and closed by an engine placed on the outside of the truss, on a level with the railroad-floor. Great care is necessary in handling this heavy draw in time of high wind. The posts are Phœnix beams. The railroad-floor beams are attached to the posts so as to form a system of lateral bracing. The bridge over the main river was built by the Baltimore Bridge Company, Mr. C. Shaler Smith, chief engineer. On account of the limitation of cost provided in the law, the specifications called for wooden floors for both rail and high way. If the means admitted, this should have been changed to iron. When it becomes necessary to renew them, iron should be substituted for the wood.

INFLUENCES ON NAVIGATION.

This bridge has met the wants of navigation as fully as a low draw-bridge is capable of doing. The locality is particularly favorable to this kind of bridge, as there is sufficient depth of water for boats and rafts from shore to shore, and the rock bed renders a change in this impossible.

ALTERATIONS TO LESSEN OBSTRUCTIONS TO NAVIGATION.

Sheer-booms.—The board of engineers on sheer-booms recommended that a sheer-boom 1,200 feet long be placed with its lower end, when in position, resting against the Davenport rest-pier.

Finishing the work in left draw-opening.—This board also recommended the timbering and planking of the rocky shore of the island for 500 feet above the bridge. This was part of the original plan, and should have been carried out if there had been funds to do it.

HIGH BRIDGE.

It is probable that this is one of the last places on the Mississippi River that will require the low draw-bridge to be replaced by a high one. When done, it should be placed at least 77 feet above low water, to enable boats to pass under it at all times when they can pass the bridge at Saint Louis. (See Discussion, Chapter iii.)

BURLINGTON RAILWAY DRAW-BRIDGE.

(Opened for railway travel in 1868.)

Authority.—This bridge was built by the Burlington Bridge Company in 1867 and 1868, under act of Congress approved July 25, 1866.

DESCRIPTION OF THE RIVER AND VALLEY AT THE LOCALITY.

(See Diagram 21.)

This bridge crosses the Mississippi River about 4,000 feet below the steamboat-landing at Burlington, Iowa. The river at this point is about 2,100 feet wide between the low-water banks, with a large extent of bottom-land overflowed 5 to 10 feet at highest water, extending to the Illinois bluffs, making the width of the high-water river about 5 miles.

The channel of the river for 5,000 feet above the bridge and 3,000 feet below runs along the west bank in a direction for the most part parallel with the shore, which is rocky. The bluffs rise abruptly from the shore except at the site of the town, which is in an opening in the bluffs through which Hawkeye Creek flows. The river for two miles above and one below the bridge is confined to one channel, in which there is always a good navigable depth. The slope of the river at low water is 0.27 foot per mile. The bed is generally sand. The depth to bed-rock is not known, except for that part from the west or right bank to the pivot-pier, where it is about 30 feet below low water. The rise from low to high water is 20 feet.

SURVEYS.

A survey was made by us here in 1866 extending about 2 miles above and 2 miles below the bridge-site. The location of the bridge had not at that time been made, or, if made, was not generally known, so that no special examinations of the bridge-site were made. The survey consisted of a meander of both shores of the river; location of sand-bars; levels to ascertain the slope of the water's surface; soundings over the section surveyed; and measurements for volume of discharge. A survey including current-observations was made in 1868 after the bridge was built. The water then was about 4½ feet above extreme low water. The maximum velocity at the bridge was about 2¾ miles per hour; that in the channel 2,000 feet above was about 2¼ miles per hour. Current-observations were again made in October, 1869, with the water 11.6 feet above low water. The maximum velocity was about 4¼ miles per hour.

DESCRIPTION OF THE BRIDGE.

(See Diagram 22.)

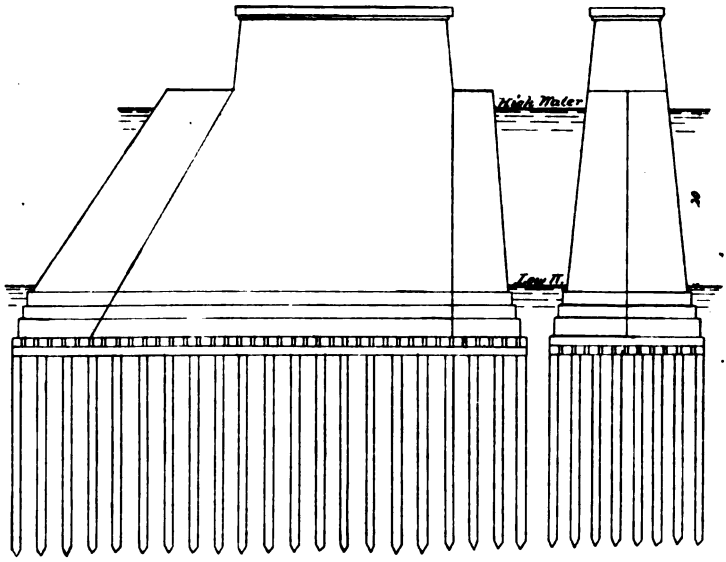
The bridge is approached from the west on an embankment with a curve of about 720 feet radius. The first span is 175 feet long from center of abutment to center of first pier—part of the span being over the land. The second span is 200 feet long. The trusses of these two spans are wider than those of the rest of the bridge, to allow the curve of the approach to be extended on the bridge. The next span is a pivot-draw 360 feet long over all, with two clear openings of 160 feet each; then there are 6 spans of 250 feet each from centers, and then trestling for a few hundred feet, which last is considered temporary and is

Burlington, Iowa.

ELEVATIONS OF PIER 5.

Scale of Feet

0 10 20 30



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to be replaced by an embankment. The whole length of the bridge is 2,235 feet.

Masonry and foundation.—The masonry is built of stone from Athens, Ill., and Le Claire, Iowa. All of the piers rest upon piles cut off about 5 feet below low water. The piers, in this report, are numbered from the right bank. The piles for foundation of piers Nos. 1 and 2 were driven to bed-rock, which was struck about 30 feet below low water. Part of the piles in the foundation of pier 3 (pivot) were driven to bed-rock. The piles in the foundation of the other piers were driven from 20 to 25 feet into the bed of the river. The distance to the rock is not known. Under pier No. 1 there were 140 piles; under pier No. 2, 170 piles; under pier No. 3 (pivot), 333 piles; under pier No. 4, 170, and under each of the others about 140. The masonry was built upon a grillage of timber, which rests upon the heads of the piles.

The dimensions of pier 5 (see Diagram C′) are, length 24 feet, width 8⅓ feet. The batter is one-half inch to the foot. At a point 9½ feet below the level of the bridge-seat, 2 feet above highest water, the starling commences. The horizontal section is in the form of an equilateral triangle, and the cut-water has a slope of 8 inches to a foot vertical. The lower ends of the piers are frustums of a right semi-cone with a circular base. Where the piers rest on the grillage the length is about 57 feet, and width 16½ feet; the lowest 5 feet being of three courses, each offsetting 6 inches all around. All the others are similar to pier No. 5 except the rest-piers Nos. 2 and 4, which are one foot wider. All of the piers except the draw-pier have detached ice-breakers; these were not built when our examinations were made in 1868, and when the bridge was surveyed in 1869 the high water prevented our examining them. The draw-rests are pile-cribs built to above high water, with their sides planked; at the upper and lower ends there are timber-cribs filled with riprap.

The *superstructure* of this bridge is of iron. The fixed spans are quadrangular girders with cast-iron upper chords. Phœnix rolled posts, and bottom chords of open links. The draw-span has both chords of rolled channel-beams riveted together. The whole superstructure was built by the Detroit Bridge and Iron Works, at the same time and under the same requirements as the bridge at Quincy. No account of the building of this bridge has been published that we know of.

INFLUENCE UPON NAVIGATION.

At the time of the examinations in October, 1868, the current measurements show that the general direction of the current made an angle of about 5° with the axis of the piers. The maximum velocity was through the west draw-opening.

A hard gravelly point makes out from the Iowa shore, about 500 feet above the bridge, which, at the time of this examination, deflected the current from the shore. This gravel-bar is probably composed of the coarser material brought into the river by Hawkeye Creek, and has become packed together so hard that it resists the action of the water even at flood velocity. This point acts differently at different stages of water; with the water high enough to run over it, it deflects the current but little; but when the water falls below, the current is deflected toward the right draw-opening, so as to cause a cross-current through this opening. The filling out of the shore-line above this point would probably remedy this somewhat; this filling had been commenced by the railroad company to make ground for depot-buildings.

We again examined this bridge in October, 1869, when the water was 11.6 feet above extreme low water. The direction of the current at that time was nearly parallel with the axes of the piers, making in the approach to the draw-openings an angle of but 4°. The maximum velocity was through the right opening of the draw, in the same locality as the maximum velocity of low water.

Passage of steamboats.—The location of a bridge below a landing is objectionable. Steamboats descending the river make the landing above the bridge with bow up stream; all boats have to do so on this river on account of the current. On leaving the levee they must turn around and get into position before they can pass through the draw; while trying to do this they are often carried down by the current so near the bridge as to compel them to back into position, thereby losing much time. Again, a boat breaking from her moorings at the landing is almost sure to be carried onto the bridge, endangering both boat and bridge. The bad effect of this location would have been much lessened if the Iowa bank had been made straight and filled out to the line of 5 feet depth at low water, as far up as Berry's Mill, and the draw placed next to the shore. This would have given a much better opportunity to pass in bad weather and dark nights. The bridge company disregarded the requirements of the law to put a 250 feet span adjoining the draw, so that the provisions of the law cannot be given as a reason for not putting the draw next the shore. This arrangement would have made the passage no worse for rafts than it now is. There is a bar above the bridge, on the left side of the channel, similar to that at Quincy, but not seriously objectionable in its influence, as it leaves a channel-way 800 to 900 feet wide.

Passage of rafts.—There are six spans east of the draw, of 250 feet each from center to center (seldom used by rafts because of the bar and set of current above them), but the span next west of the draw, in violation of the law, is but 200 feet. The channel for some distance above the bridge being along the Iowa bank, rafts are generally brought down that shore, since, by so doing, they are sheltered by the bluffs from winds. Upon approaching the bridge, if the raft is too wide to pass through the 200 feet span it must be moved sidewise about 500 feet, across the swiftest part of the current, so as to pass through the first 250 feet span on the left side of the draw-openings. This is an operation so difficult as to be seldom undertaken by a raft without employing steam-power.

The position of the gravel point before alluded to renders the use of the 200 feet span quite difficult at a medium or lower stage of water. The usual manner of passing rafts when managed by means of a steamboat is to divide them into two parts above the bridge, and take one through the 200 feet span and the other through the draw-opening. In passing the 200 feet span they are drawn by the current toward the Iowa pier in high water and toward the other pier in low water.

ALTERATION TO LESSEN OBSTRUCTIONS TO NAVIGATION.

Sheer-booms.—The board of engineers in their report on sheer-booms recommended that a boom should be extended 900 feet up stream with its lower end resting against or attached to the right rest-pier. The raft interest desired that another boom 1,000 feet long should be placed on the upper end of the draw-rest extending up stream and flaring toward the Illinois shore, showing that they do not care to use the present 250 feet span. But this boom would interfere with the passage of the bridge

by steamboats, and could not be allowed. This want of the raft interest shows that the long spans to the left of the draw are of little or no use for passing rafts.

Change of span.—A change which the raft interest would have a right to demand is a reconstruction of the span on the Iowa side of the draw so as to make it 250 feet. If this should be done the shore end should rest on an abutment, and the shore-line brought out to a line joining the abutment and Berry's boom-pier about 700 feet above. The opening thus provided and the point above should be dredged out 3 to 4 feet depth at low water. With this change it is thought that no sheer-booms will be needed at this bridge.

HIGH BRIDGE.

The building of a high bridge at this place would not involve great expense for approaches, as the Iowa approach offers a choice of high or low ground, while that on the Illinois side is low and not valuable. A high bridge at this place should be 77 feet above low water, or 57 feet above high water.

KEOKUK RAILWAY AND HIGHWAY DRAW-BRIDGE.

(Opened for travel in 1870.)

Authority.—This bridge was built in 1869 and 1870 by the Keokuk and Hamilton Bridge Company, under act of Congress approved July 25, 1866.

DESCRIPTION OF RIVER AND VALLEY AT THE LOCALITY.

(See Diagram 23.)

The river in its natural condition at this place is about 2,600 feet in width at ordinary low water, and about 5,500 feet in width at flood stages. The bed of the river is limestone, of the same character as that of the whole of Des Moines Rapids, which extend from this place to Montrose, about 11 miles above. The slope of the river for this distance averages about 2.2 feet per mile, but in places in the lower part of the distance it is as much as 3 feet per mile. Immediately below the bridge the low-water width increases, the slope becomes small and the rocky bed is replaced by sand. The rise from low to high water is about 22 feet.

SURVEYS.

A survey of about 1½ miles of river was made at this place in October, 1866, after the passage of the act authorizing this bridge, but, as the location had not then been made, the survey was made general over a section supposed to include its probable site. The water at the time of making the survey was about 2.5 feet above low water. After the location of the bridge had been determined upon and work commenced another survey was made; this was in October, 1869, when the water was 12.8 feet above low water. Again, in October, 1876, after the bridge was opened and the canal nearly completed, another examination was made with the water 5.8 feet above low water. The results of the two last examinations are taken up in treating of the "Influences upon navigation" of the bridge.

DESCRIPTION OF BRIDGE.

(See Diagram 24.)

Arrangement of spans.—The river is spanned by twelve spans of the following lengths, commencing at the Keokuk side and measuring along the axis of the bridge and from center to center of piers: First, a pivot draw-span 380 feet long from end to end; this length was intended to give openings of 160 feet at right angles to the axes of the piers. Then come spans of 258 feet, 256.3 feet, 162.6 feet, 162.5 feet, 163 feet, 151.5 feet, 164.9 feet, 165.1 feet, 164.3 feet, and 165 feet, respectively, making the total length of bridge about 2,190 feet. On the Illinois side there is a high embankment for 1,930 feet; about 500 feet of this is in the low-water channel-way, but the old transfer embankment above it still stands and occupies a greater space of the water-way; there is next a single span of 95 feet over a slough, and then the embankment is continuous to the high ground, a distance of about 1,200 feet, making a total length of bridge and embanked approach on the Illinois side of 5,475 feet. The approach on the Keokuk side is over a structure of masonry on a curve of about 850 feet radius, the abutment being about 160 feet from the shore-line. The Illinois approach and the bridge are on a straight line. The Keokuk end of the bridge is about 900 feet below the lower end of the Des Moines Rapids Canal, now about completed.

Substructure.—The piers are constructed of limestone, the greater part of which came from quarries in the immediate vicinity. They rest (or part of them do) upon a timber grillage, and this upon the rock of which the bed of the river is composed. The pivot is circular, provided with slots in which the ends of the floats between the pier and rests slide, as water rises and falls. The rests are built of timber, filled with riprap. Between the pivot-pier and the rests is a crib-work built up to a height a little above low water. Above this is the float.

In October, 1876, these floats were much out of repair, and were prevented from resting on the cribs by drift-wood lodged between them and the cribs.

The piers and draw-rests are built with their axes at an angle of 72° 45′ with the axis of the bridge, so that the openings between them are not that represented by the length of the spans, but by this length into the sine of the angle which the axes of the piers make with the axis of the bridge, so that the draw-spans of 190 feet from center of pivot to center of rest-pier are but 181.4 feet when measured at right angles with the axes of the piers.

Superstructure.—The bridge was built by the Keystone Bridge Company of Pittsburgh, Pa., in 1870. It is of wrought iron throughout except the head and foot of posts and angle-plates of upper chords, which are of cast iron. The trusses are 21 feet high except the draw-span, which is about 35 feet at the center and 21 feet at the ends. The trusses are 23 feet wide from out to out, with sidewalks 5½ feet wide on each side. The floor-beams are of two channel-beams 10 inches deep; these are trussed, and extend outside of the main trusses to support the sidewalks.

The bridge was built for rail and highway travel on the same floor. The whole bridge, including sidewalks, is floored over at the same level, the top of the track being about 1 inch above this floor.

The draw is turned by a small steam-engine on the turn-table, the greater part of the machinery being below the floor of the bridge. Provision is also made for turning it by hand.

The bed of the river at this bridge being of rock, makes the question of contracting the water-way an important one, as every obstruction placed in it must increase the velocity.

In October, 1869, when the water was 12.8 feet above low water, we measured the velocity at this place. The canal-lock was then in process of construction and occupied about 400 feet in width of the low-water section; the transfer approach on the Illinois shore extended into the low-water river about 700 feet, at a point about 100 feet above, leaving a low-water width of but 1,700 feet, and at the stage 12.8 feet above low water a width of 1,900 feet.

The piers of the bridge were not built. The maximum velocity was about $4\frac{1}{2}$ miles per hour.

In October, 1876, we again measured the velocity here with water 5.8 feet above low water, with the same width of water-way except the additional obstruction of the piers of the bridge. The maximum velocity was then about 3 miles per hour. This was through one of the long spans to the left of the draw-span.

INFLUENCES UPON NAVIGATION.

At the time of our examinations, in 1869, the site of the bridge had been fixed upon and the approaches were nearly built, but no piers had been built in the river. As no obstructions had been placed in the river the direction of the current was the same as when the location of the bridge was determined upon. The current at that time approached the line of the axis of the bridge at an angle of 65°, or at an angle of $7\frac{3}{4}$° with the axes of the piers as afterward built. The water at that time was 12.8 feet above low water.

When our examinations were made, in October, 1876, the greater part of the right-hand draw-space was obstructed by a coffer-dam put in by the government in order to deepen the channel from the foot of the canal-lock down through the right draw-opening. This dam extended from the lower end of the canal-bank down to the upper draw-rest. In this distance about 250 feet had been partially removed, but, as it was nearly parallel with the general direction of the current, it was impossible for a steamboat to use it, and, as the canal was not in use, the right-hand draw-opening was entirely unavailable for the passage of rafts or steamboats. The existence of this coffer-dam prevented the water from being drawn into this opening and was therefore favorable to a direct flow of the current through the left draw-opening and adjoining long spans. Had the space between the canal-wall and head of upper draw-rest been open, there must have been a strong current into the tail-bay of the canal. The existence of such a current would make the passage of the left draw-opening difficult, and at times of high water very dangerous. With this opening so nearly closed the general direction of the current made an angle of 6° with the axes of the piers, and $66\frac{3}{4}$° with the axis of the bridge. The clear opening in the left draw-space, measured at right angles to the general direction of the current, was about 125 feet. This distance was measured at right angles between two parallel lines drawn in the general direction of the current—one from the lower end of the lower draw-rest, the other tangent to the west face of the left rest-pier. This is not the full width between the piers, but the unobstructed width in the line of current. This bridge, as it at present stands, is a marked case of the violation of that provision in the law under which it was built, which requires that the piers shall be parallel with the current, and is, in consequence, the worst bridge for the passage of rafts, and

one of the worst for the passage of steamboats, on the Mississippi River. Its location at the foot of rapids on which there is no landing place for rafts makes its bad features more dangerous than they would have been in an ordinary place on the river.

ALTERATIONS TO LESSEN OBSTRUCTION TO NAVIGATION.

It is thought by some that the extension of the draw-rest up to the canal-bank would make the passage of the left draw-opening less dangerous than now. If it were built solid and raised so as to keep out the current at highest water, there would be a strong current across the lower end of the draw-rest into the right draw-opening, which would then be simply the tail-bay of the canal-lock, whose level at the lock would be that of the river at the lower end of the draw-rest. If this were practicable, it would probably somewhat facilitate the passage of the bridge by steamboats and rafts; but it is also probable that it would so interfere with the use of the canal that it could not be allowed. To lessen deposit below the canal-lock it will probably be necessary to have the space between the canal and draw-rest left entirely open. We shall then have the strong cross-current above the upper draw-rest that will endanger every descending boat and every raft that attempts to use the long span to the left of the left draw-opening.

A medium course between the two previously suggested might be taken by connecting the lower end of the canal-bank with the upper end of the upper draw-rest by cribs and booms. The design of this should be such as to leave sufficient openings between the cribs to preserve the level of the water at the foot of the canal-lock nearly the same as if left entirely open. It would at the same time answer the purpose of a fender along which boats might drop through the draw-opening. It might be, however, that the draught of water under these booms would be so great as to pull log-rafts to pieces when floating against it. The loose logs would be drawn into the tail-bay of the canal, occasioning delay and loss to the raftsmen and annoyance to the steamboats using the canal. These three ways seem to be the only ones that offer any promise of alleviating the difficulties, and neither of them affords a satisfactory solution. The bridge should never have been built in such proximity to the canal entrance.

Sheer-booms.—The board of engineers on sheer-booms recommended that a boom be placed between the head of the draw-rest and the foot of the canal-bank; that another, 1,200 feet long, be placed with its upper end 600 feet from the canal-bank, and its lower end against the left pier to the left of the first long span to the left of the draw.

Enlargement of section.—The substitution of open bridge for so much of the embankment as now occupies the low-water river, might afford some alleviation by increasing the water-way and decreasing the velocity.

But at best, none of these devices afford more than a partial remedy. The defects of its location in connection with the canal are so great as to demand the removal of the bridge and its erection elsewhere. With its removal the Iowa shore-line could be brought into suitable form for the canal approach, which cannot be done with the existing structure.

HIGH BRIDGE.

The only unobjectionable plan for a bridge at this place is for a high bridge crossing the stream at right angles to the general direction of the current. It should be so located that one pier would be placed near

the lower end of the canal-bank. It should have two high spans, one 200 to 300 feet in the clear over the canal, and the adjoining one 300 to 400 feet long in the main river. These high spans should give at least 56 feet headway at times of highest floods, to allow for the passage of steamboats at any time when they can pass the Saint Louis bridge. The other spans should not be less than 250 feet long and might be either deck or through trusses, *provided*, that the lowest parts of none of the spans be less than 10 feet above highest water. This plan would leave the full low-water width of the river, and as trestles or short spans would probably be used in the approaches, additional high-water width could be given. A tunnel through the rock under a portion of Keokuk would be required, for which an outlet in a ravine below Main street can be found.

QUINCY RAILWAY DRAW-BRIDGE.

(Opened for travel November, 1868.)

Authority.—This bridge was built by the Quincy Railroad Bridge Company in 1867 and 1868, under act of Congress approved July 25, 1866.

DESCRIPTION OF THE RIVER AND VALLEY AT THIS LOCALITY.

(See Diagram 25.)

This bridge crosses the Mississippi River about one mile above the landing at Quincy, Ill. This site was chosen because of the channel being permanent along the Missouri shore, thus furnishing a good location for the draw. The bed-rock is but from 35 to 45 feet below low water. The width of the river between the low-water banks is about 3,000 feet.

There is a small slough on the Illinois side, called Quincy Bay, which the bridge crosses near its mouth. As the river approaches the town of Quincy the channel crosses to the Illinois side, where the banks are high, and continues along the shore for about one mile. It then turns to the right, and has low land on both sides of the banks until it reaches the bluffs, 2 miles above Hannibal and about 18 below Quincy. The width of the valley, between the bluffs, is from 5 to 7 miles. This whole area is covered at times of highest water to a depth of from 5 to 8 feet. The rise from low to high water is about 20 feet. The water slope is about 0.4 foot to the mile.

SURVEYS.

At the time of our survey of this locality, in October, 1866, the location of the bridge had not been announced, so that we could make only a general survey covering some 4 miles of river. The survey would have been more minute at the point where the bridge was to be built if we had had actual knowledge of its future position.

This survey consisted of a meander of both banks, and of the island opposite Quincy; of soundings over the whole of the river surveyed; and observations for volume of discharge. A survey of the site of the bridge was made in November, 1868, which gave us all the information desired at that stage of the river, including observations for direction and velocity of current.

DESCRIPTION OF THE BRIDGE.*

(See Diagram 26.)

Commencing on the Missouri side, the bridge is approached by a long embankment, with occasional openings in it to allow for the passage of flood-water when the bottom is overflowed, and for the drainage of the bottom-lands.

The first span is 250 feet, partly over the land; the next, a pivot-draw 362 feet long with two openings, each 160 feet in the clear; then, a span 250 feet long; then, two spans, each 200 feet long; then, eleven spans, each 157 feet long; and then, next to the shore of the island, one span of 200 feet. An embankment of 670 feet extends across low land to Wood's slough; then comes 400 feet of trestling across this slough; then, 285 feet of embankment to the bridge over the bay. This bridge has six spans: first, one of 82½ feet; then, one of 85 feet; then, a pivot-draw 190 feet long, with 80 feet clear openings; then, a span of 85 feet, and another of 82½ feet. The draw on this bridge is required by an act of the Illinois legislature.

The main bridge extends from bank to bank of the low-water river, so that the 17 piers in the river, with their protection, is the amount of contraction in the low water water-way. This amount is relatively very small, as the whole width is about 3,100 feet. A small increase in velocity would probably soon scour out the bed to fully compensate for the obstruction, and as the bed is composed uniformly of fine sand, the scour will not be likely to occur to a dangerous extent in any one part of the cross-section.

The length of the bridge over main river is 3,185 feet, and over the bay 525 feet, making, with trestling and embankment on the island, 5,068 feet from abutment on Missouri shore to abutment on Illinois shore. Over the main channel the bridge is on a straight line. There is a short 4° curve on the island, then a straight line across the bay bridge, and then a curve to the junction with the track of main line.

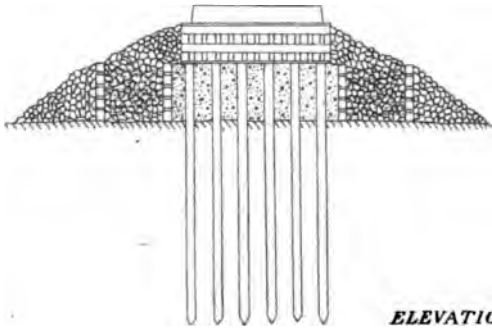
Substructure.—The masonry of substructure is of stone from Grafton, Ill., and Keokuk, Iowa. All the piers in the main river, except the pivot, and all in the slough rest upon wooden piles. The pivot-pier in main channel rests upon four iron cylinders, each 14 feet in diameter and 30 feet long. These cylinders were sunk to bed-rock by weighting and dredging out the sand from inside of them. They were filled with concrete, lowered in a concrete-box and leveled by a diver.

The masonry of this pier was built in a water-tight caisson, the bottom of which was a grillage of 3 courses of timber 12 inches by 14 inches, laid 4 inches apart, and covered with 2-inch planks. This caisson was placed in position over the cylinders, and the masonry laid inside sunk it down upon the cylinders. When the masonry was built above the water-surface the sides of the caisson were detached from the bottom. Piers numbered 2, 4, and 5, in deep water rest on wooden piles. (See Diagram D.) The piles under 2 and 4 were driven to bed-rock; those in the foundation of pier 5 down about 25 feet. A crib was then sunk around the heads of the piles, which were sawed off at 5½ feet below low-water, and the space between them filled with riprap and concrete. A grillage consisting of three courses of timber was floated into place and suspended by ten screws 2¾ inches in diameter, having four threads to the

* A portion of the data for this description is taken from "An account | of the | iron railway-bridge across the Mississippi River | at | Quincy, Ill., | by | Thomas Curtis Clarke, C. E., | Engineer in Chief, | illustrated by twenty-one lithographic plates. | New York: D. Van Nostrand, publisher, | 23 Murray street and 27 Warren street, | 1869."

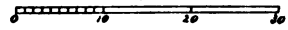
Quincy, Ill.

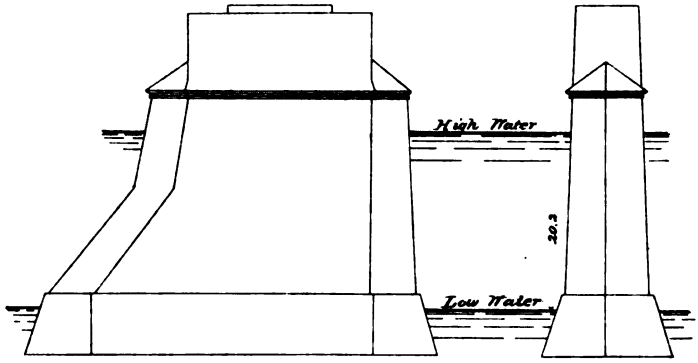
FOUNDATION



ELEVATIONS OF PIER 4.

Scale of Feet





AM. PHOTO-LITHO. CO. N. Y. (OSBORNE'S PROCESS.)

inch. The masonry was built upon this grillage and the whole lowered into position by these screws; some of the grillages were thus lowered as much as 15 feet.

From pier 6 to the east shore the cribs had to be sunk before the piles were driven, on account of the sand. Before sinking these cribs the sand had to be dredged out. After the cribs were sunk the piles were driven from leaders resting on the cribs and sawed off, concrete being placed about and between their heads. The foundation of the abutments of both main and slough bridges was formed by inclosing the space with sheet-piling, and then excavating to 2 feet below low water. A foundation of concrete 2 feet thick was then put in and the masonry laid upon it. All of the piers were built with a rough ashlar stone-face backed by concrete.

Detached ice-breakers were built to piers 2, 4, 5, 6, and 7. These ice-breakers are constructed of 22 piles driven in the proper form, the outer row sawed off 1 foot below low water. A crib 20 feet by 45 feet is sunk around these and filled with riprap to within 2 feet of low water, and riprap is placed outside to protect it. The ice-breaker resting upon these piles is built of oak timber 9 inches by 9 inches, sheathed with ½-inch boiler-plate and finished with 4-inch angle-bar running the whole length of the nose. Each ice-breaker is filled with concrete from 2 feet below to 8 feet above low water. The upper guard-rest is built to serve as an ice-breaker. Between the guard-rests and pivot-pier are cribs resting upon piles. These piles are sawed off about 4 feet above the sand-pockets or compartments, which were filled with riprap. The cribs are built up to 6 feet above low water. Upon each of these cribs rests a float of white-pine timber. The sides of these floats are of 2 courses of 12 inches by 12 inches, sheathed with 4-inch plank and united by diagonal ties and bracing 12 feet apart. The ends of the floats are provided with cast-iron rollers, which run in slots in the masonry of pivot-pier and in the upper and lower guard-rests to allow them to rise and fall with the water.

Superstructure.—The superstructure was built by the Detroit Bridge and Iron Works. The fixed spans of the main bridge are quadrangular girders with cast-iron upper chords, Phœnix-rolled posts and bottom chords of open links. In the draw over the main river both chords are rolled channel-beams riveted together. The width between all trusses over the main river is 14 feet; their heights vary. The 250-feet span is 26 feet high, the draw-span 26 feet high at ends and 34 feet at the center; the 200-feet spans 24 feet; eleven spans of 157 feet are 22 feet high, and the 200-feet span next to east shore is 22 feet high.

The bridge over the bay is a Bollman truss with cast upper chords and posts. The draw is the same with riveted upper chords, supported by hog-chains over a central tower. The spans in the bridge are all 10 feet high, with track on top of upper chord. These trusses are 10 feet wide. The draw over the main river is turned by a small steam-engine placed on the turn-table outside of the truss. It is also provided with means of turning by hand. The draw in the bridge over the bay is turned by hand.

INFLUENCE UPON NAVIGATION.

At the time of our examinations in 1868 the water was about 5 feet above low water, and 15 feet below extreme high water. The west draw-opening was temporarily unavailable by reason of the sinking of the steamer *G. D. Palmer* and two barges a short time before. These ran upon the upper draw-rest and sank in the west opening. A sand bar

forms above the bridge, and frequently when low water occurs it occupies the greater part of the water-way.

Mr. T. C. Clarke, the engineer of the bridge, in his published account, says it is constantly encroaching on the channel at low water, and as constantly being swept away again at high water. The only danger is that a portion of the discharge at low water may find its way down along the east shore, diminish the volume of flowage in the main channel, and allow the bar to encroach too far. This actually occurred during the summer of 1868, but was effectually stopped by building a low wing-dam on the Illinois shore, which confined the current to the main channel.

Our current-observations show the current to approach the bridge at an angle in the first 1,000 feet above the bridge of 6°. This direction and the position of the bar make the east draw-span difficult to reach from above by reason of this bar approaching within 800 feet of the upper end of the draw-rest measured in prolongation of its axis.

The width of the channel between the bar and the west bank was about 400 feet. The middle of east draw-opening is about 500 feet from the west bank, so that descending boats were obliged to hug the bar very closely to go through it. Boats heavily loaded, or with tows, were sometimes compelled to stop a short distance above the bridge and back until they got into position for running through this opening.

This difficulty in using the left draw-opening would not have been so great if the pivot had been placed with the right draw-opening next the Missouri shore. There would besides have been the further advantage to navigation in this position that, in time of high winds, dark nights, or thick weather, vessels could have hugged the shore and been thereby safely guided into the draw-space, or by passing lines to the shore might drop down or warp up.

The constructor of the bridge foresaw this, but was apparently controlled in the course he took by the feature of the law which prescribed that the "next adjoining spans shall not be less than 250 feet." This provision is really a defect in the law. In many cases it is impracticable to carry it out without great injury to navigation. In some places besides this, to be mentioned hereafter, it has been but partially met, and in several others neglected, as at the new Rock Island, Winona, and La Crosse bridges, where the draw is placed next the shore. In the course pursued at Quincy bridge, the constructor either neglected another provision in the law or demonstrated another defect in it. These spans of 250 feet were provided for the use of rafts, which at least implied that they should be spans over the water-way at times when rafts were running. But as a part of the span is over the land (the support on which it rests being 30 feet inside of the ordinary low-water line), it allows 30 feet less for the rafts than there should have been. If this is allowable, there seems no reason why the whole span could not, by the same interpretation, have been placed out on the low-water bank, thus placing the draw next the shore. To have placed the Quincy draw next the shore would have made both draw-openings at all times available, but the 250-feet span on the side away from the shore would have been difficult for rafts, although not so much so as it now is. On the other hand, to have made the full 250-feet span between the draw and the Missouri shore available would have increased the unfavorable influence of the bar upon the use of the draw-opening farthest from the shore, while making more favorable the passage of rafts. On the whole, the present conditions are somewhat of a compromise upon the facilities

for steamboats and rafts, and illustrate the difficulty, if not impossibility, of making a low draw-bridge meet all the requirements of river navigation. The difficulties noted here are small compared with what are developed by the same irreconcilable demands elsewhere, where the current is more rapid.

ALTERATIONS TO LESSEN OBSTRUCTIONS TO NAVIGATION.

Sheer-booms.—The board of engineers on sheer-booms recommended that a sheer-boom 1,000 feet long be so placed that its lower end would rest against the left rest-pier, with its upper end 650 feet from the right bank, to direct the rafts towed by steamers through the east draw-space when by reason of wind they cannot use the west space.

Widening of the Missouri shore span.—This span is required, by that interpretation of the law which prevents the draw being placed next to the shore, to be 250 feet for the use of rafts. The placing of the abutment 30 feet from the shore takes that much off the span thus required, and compliance with the law necessitates a change. This change can be made by removing the riprap now protecting the shore back to the line of the face of the abutment for half a mile above the bridge, so as to allow the river to scour out its channel up to this line, and rebuilding the abutment on suitable foundations. This will give an excellent passage-way for rafts, but it would allow the bar above the bridge to move 30 feet more toward the Missouri shore, and thus render the use of the left draw-opening more difficult for steamboats. On the whole, it is probably best not to make this change.

Works to control the formation of the bar above the bridge.—Without very extensive works requiring the complete rectification of the river for some considerable distance (2 or 3 miles) it would be impossible to so govern the action of the water as to secure a wider channel between the bar and the Missouri shore. Its width at low water is thus limited by natural conditions to about 400 feet, and we cannot readily increase it.

INCOMPATIBILITIES OF THE LAW FOR BUILDING DRAW BRIDGES.

A little consideration of this case shows the difficulty of framing a law to meet the wants of navigation until the features of the river at the proposed location are ascertained.

If we provide for the steamboat navigation first and for the rafts second, we should (at the site of the Quincy bridge) undoubtedly place the draw-span next the Missouri shore, and it would occupy about 365 feet of the channel.

There would then be no space adjoining for a navigable raft-span of 250 feet that could be used in the low-water period, for if even a wider space exists at the bridge site, the projection of the bar above it prevents its being entered. Rafts in such cases must use the draw-opening. If the raft-span is placed next the shore, then the efficiency of one draw-opening is almost completely destroyed at low water, and the use of the other at times of high wind and dark nights is also made very difficult, if not impracticable. Drawbridges at such places have therefore to meet irreconcilable wants of navigation. The only thing to do seems to be to make the best location of the draw-openings, and afterward such further provisions for rafts as the case admits of. The wide spans should still be employed in all cases where they might be of use to rafts in stages above low water.

HIGH BRIDGES.

The high bridge is the only kind that can be made here to suit all the wants of steamboat, barge, and raft navigation. A high continuous-span bridge at Quincy was particularly feasible, as the Quincy approach is on high ground, and there is ample room on the west bank to get down without expensive land damages. It should give a clear headway of not less than 57 feet at high water or 77 feet at low water, and the channel-spans should not be less than 300 feet in the clear.

HANNIBAL RAILWAY AND HIGHWAY BRIDGE.

(Opened for travel in 1871.)

Authority.—This bridge was built in 1871, under act of Congress approved July 25, 1866.

DESCRIPTION OF THE RIVER AND VALLEY IN THE VICINITY.

(See Diagram 25.)

This bridge crosses the river at a point about one mile above the steamboat-landing of Hannibal, Mo., about 17 miles below Quincy. The river at this point is nearly all in one channel, and is very narrow and deep. About one-half mile above (where the river first strikes the bluff on the right bank), the river bends sharply through an angle exceeding 90°; the width is only about one-fourth mile, being one of the narrowest points on the river. It was a noted crossing-place for the Indians in their day.

The low-water width of the river at the point where the bridge is located is about 1,500 feet. Prior to the building of the Sny Carte Levee, the high water spread out from bluff to bluff 6½ miles, but the levee narrowed the high-water width at this point to about 2,300 feet.

The Sny Carte Slough is a small channel, *chénal écarté*, which leaves the main river about 4½ miles above this bridge and joins the river about 33 miles below. This channel was closed and the whole bottom leveed in from the head of the slough to its outlet. The effect of this was to confine all the flood-waters to the main channel, causing their greater volume and velocity. This levee gave away April 17, 1876, at 2 p. m., with the water at 19.6 feet on the bridge-gauge, and rising. On the morning of the 18th, the reading was 19 feet on this gauge, while it had not fallen at Quincy. The rise from low to high water is about 22 feet. The slope, as measured by us, near low water, is about 0.4 foot per mile.

SURVEYS.

In November, 1866, we surveyed about 3 miles of river from 1½ miles above to 1½ miles below Hannibal. The low banks were fixed, soundings taken over the whole distance, and the slope measured and observations for volume of discharge made. This was all that could be done, until the position for the bridge had been chosen; the water was then about 1.7 feet above low water. The volume was 52,000 cubic feet per second. In October, 1876 (after the bridge was built), we again made surveys and examinations. The water was 6 feet above low water.

DESCRIPTION OF THE BRIDGE.

(See Diagram 27.)

On the Missouri side the bridge is approached through a short tunnel on a 9½° curve, to which the bridge axis is tangent. The line of the

bridge is at right angles with the general course of the river. The spans of the bridge commencing at the Missouri side are, first, one 250 feet from centers of piers; then a draw-span 360 feet over all, giving two clear openings of 160 feet; then one span 250 feet, and four of 180 feet each, making the total length of the bridge 1,580 feet. The line of the bridge is prolonged by an embankment of 400 feet from the Illinois end, which is continued by a 6° curve for about 1,100 feet. The Toledo, Wabash and Western Railway continues in a southeasterly direction for several miles in the bottom-lands of the river.

Another railroad, known as the Chicago, Alton and Saint Louis, but lately in the hands of the Chicago, Burlington and Quincy Railroad Company, also uses the bridge. This line leaves the other road 900 feet from the Illinois end of the bridge, and runs to Quincy; it uses the track of the other on the Missouri side of the river.

Substructure.—The substructure, commencing at the Missouri abutment, is first an abutment of masonry resting on the rock of the bank; this abutment is about 25 feet from the low-water line of the river. The draw or pivot pier is of solid masonry, resting on piles. The up and down stream sides are straight lines, 21½ feet long in the direction of the bridge, while the sides next the current are arcs of circles. The width of the pivot at right angles to the bridge axis is about 36 feet. The other piers are of solid masonry, upon a grillage resting upon piles. The piles of the two piers next to the Illinois side were cut off above extreme low water. The stone for these piers was obtained chiefly from the neighboring bluffs, but some came from the quarries near Joliet, Ill.; they are of nearly the same form and dimensions as those at Quincy. The guard-rests are cribs filled with riprap. The ends next the pivot are formed to receive and hold in place the floats which occupy the space between them and the pivot-pier. These floats rise and fall with the river. The part of the embanked approach on the Illinois shore, commencing 700 feet from the end of the bridge and leading down the valley for some distance, is used as a part of the Suy Carte Levee. At the time of the high water of April 17, 1876, this embankment gave away at a point about 1,400 feet below the bridge; this break was about 600 feet wide and scoured out to the depth of 18 feet below the general surface. The levee gave away on the same day at the head of the "Suy Carte."

Superstructure.—The superstructure was built by the Detroit Bridge Company. The draw is wrought iron in all its parts. The other spans are all of wrought iron except the top chords, which are cast. The 180-feet spans are 22 feet high and 21 feet wide. The 250-feet spans are 25 feet high. The draw-span is 25 feet high at the ends and about 35 feet in the center. This draw is turned by a steam-engine located between the trusses above the roadway. The engine drives a horizontal shaft, which drives two vertical shafts (one at each end) that turn the draw. It is claimed by the engineer in charge of this engine that he can handle the draw with ease, even in time of high winds; that he can, by the aid of a friction-brake on the horizontal shaft, stop it in any part of its course; that there has never been a time when a boat could pass the bridge that he has not opened it, and that he has frequently opened it when the wind was so strong that boats would not attempt to run through it. The wagon-way is on the same floor and same level as the railway. Vehicles are not allowed to enter the bridge while a train is on any part of it, and a train is not permitted to enter while a vehicle is on it. The bridge has no sidewalks.

INFLUENCE UPON NAVIGATION.

Steamboats.—The draw-span is 360 feet over all, and gives two clear openings of 160 feet each; the right opening, being more under the protection of the high bluff, and also in line of the channel of the river for some distance above, is the most used. The passage of the bridge by boats at time of low water is attended by but little difficulty or risk; the current, as before stated, is nearly direct for some distance above and below. The maximum velocity, with the gauge 6 feet above low water, is about 3 miles per hour. At high water, the velocity is so strong that boats of small power cannot stem it. At such time it is a very dangerous obstruction, because the draw is located in the swiftest current, needing only a small accident to machinery or a single turn of the wheel too much to cause a serious accident. The case given below of the accident to the *Dictator*, considered one of the most powerful boats on the river, shows how great this danger is. The *Dictator*, a large towboat, with an ice-barge in tow, attempted to pass up through the bridge on the morning of the 17th of April, 1876. When just through the right draw-space, the current struck the bow of the barge, which was some distance in advance of the bow of the steamer (as is the custom in towing there), and swung barge and boat around to the west rest-pier and long span. This 250-feet span was carried away, the boat and barge sunk, and nine or ten lives lost. At the time of this accident the gauge on the draw-pier indicated 19 feet 6 inches, and at 1 p. m. of that day 19 feet 7 inches. The highest water noted is that of 1859, which on this gauge was 22 feet.

Passage of rafts.—The first span next to the right bank is 250 feet from centers of piers, but the abutment is placed on the bank so far back that the full width of the span is only available at high water. At the time of our examination, the shore-line was upward of 20 feet outside of the face of the abutment; and a tangent to the shore-line for 1,000 feet above the bridge lay 40 feet outside the face of the abutment, so that the available width between the shore and the first pier was at this stage only 200 feet instead of 240 feet, as it would have been had the abutment been placed on the shore at low water line. Then the passage of this bridge by rafts would have been much easier, and its passage by boats not made materially worse. The right draw-opening is frequently used by rafts, particularly when towed, because they fear to run close enough to the rocky shore to allow them to use the shore-span, and because, by using the draw-span, they save the trouble of unfastening and refastening to the raft. The passage of this draw-opening by rafts is attended with difficulty, as it is not wide enough and the current sets toward the right bank. While we were making our observations at this bridge, a raft, being towed by a steamer, in attempting to pass through this span, was carried against the west pier after getting more than half-way through. This set of current is caused by the channel crossing to the right bank about 2,000 feet above the bridge. For 1,000 feet above the bridge our observations show that the current is almost parallel with the axes of the piers; but this distance, although probably sufficient for boats to straighten themselves in before passing the bridge, is not sufficient for a raft to have its direction completely changed, so the motion toward the right bank continues down as far as the bridge or farther. This set of the current toward the right bank makes the use of the draw by rafts not towed by steamboats almost impossible, and I believe it is seldom attempted.

ALTERATIONS TO LESSEN OBSTRUCTION TO NAVIGATION.

Sheer-booms.—The board of engineers on sheer-booms recommended that a sheer-boom be placed along the right bank above the bridge, with its upper end attached to the shore, the lower end to be moved to the right rest-pier when in position for the passage of rafts through the draw, and to rest against the shore when used for rafts passing through the shore-span. The long span to the right of the draw cannot be made available to its full width without great expense, as the shore is high and rocky. The passage of this bridge by boats might be facilitated by the extension of the left rest-pier 1,000 feet up-stream in the line of the current. This extension should be built up above highest water, to allow boats to land against, and drop or slide through the draw. It could also be used to "warp up" by when the current is too strong. This would not interfere with the passage of the bridge by rafts, as the left 250-feet span is not used by them.

HIGH BRIDGE.

A high bridge at this place would require to be placed 55 feet above high water and 77 feet above low water. The right bank is high, so it would require only one long approach. If a high bridge were built at this place it should have high spans over the whole low water river with clear widths of 300 feet, so as to allow boats to use that part of the river in which the current is the most gentle.

LOUISIANA RAILWAY BRIDGE.

(Opened for travel December, 1873.)

Authority.—This bridge was built under authority of an act of Congress approved March 1, 1871, entitled "An act to authorize the construction of a bridge over the Mississippi River at Louisiana, Mo.," and an act approved June 4, 1872, entitled "Act further regulating the construction of bridge across the Mississippi River." The act approved March 1, 1871, required, for the first time on the Mississippi River, that a bridge should have clear draw-openings of 200 feet; and the act of June 4, 1872, required that the proposed location of the bridge should be submitted to the Secretary of War for approval before commencing the erection of the bridge, which requirement was not in previous laws. (See quotations from this law in the account of the La Crosse bridge.)

The matter of plan and location of the bridge was referred to a board of engineers by the Chief of Engineers, General J. H. Simpson, president, and they made a report, dated at Saint Louis, Mo., June 21, 1873, and printed in Annual Report of the Chief of Engineers, 1873, pp. 577–585, requiring a modification of the plan submitted by the chief engineer of the bridge, and the building of certain accessory works for controlling the channel. They also recommended a certain system of lighting the bridge, which matter had heretofore been left wholly in the hands of the bridge authorities. The bridge was built by the Louisiana and Missouri River Railway Company in 1873.

DESCRIPTION OF RIVER AND VALLEY AT THE LOCALITY.

(See Diagram 28.)

The river at the site of the bridge is about 3,700 feet wide at low water; the high water width is several miles. An attempt has been

made to confine the high water to a width at this place of about 4,000 feet. This was done by the Sny Carte Levee Company to reclaim a large tract of land between the low water river and the bluffs, referred to in the discussion of the Hannibal bridge. They constructed a levee from the high ground on the Illinois shore below Quincy to about 8 miles below this space.

The river runs along the foot of the Missouri bluffs from the mouth of Salt River, 2 miles above, to some distance below this bridge. Noix Creek joins the river a few hundred feet above the bridge. The bottom of the river is composed chiefly of fine sand, with gravel and pebbles near the right bank.

SURVEYS.

No surveys were made by us at this place prior to the building of the bridge. We made surveys and examinations at the bridge in October, 1876, when the water was 4.8 feet above low water. The maximum velocity at that time was about 3 miles per hour. The range from low to high water is given by the bridge engineers as 20.5 feet.

DESCRIPTION OF BRIDGE.

(See Diagram 29.)

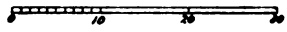
Commencing on the right bank, the abutment is approached by an embankment on an 8° curve, 450 feet of which is in the low water river. The first span is 162 feet to the center of the draw rest-pier; then a draw-span 444 feet over all, with two clear openings of 200 feet each; then a span 256 feet; then one of 226½ feet; and then six spans of about 161 feet each from centers of piers, making a total length of bridge of 2,053 feet. From the Illinois end of the bridge there is 1,500 feet of embankment in prolongation of the bridge axis, and then 700 feet on a 6° curve, making 2,200 feet of embankment in all on the Illinois side. At the inshore end of this embankment, the Quincy, Alton and Saint Louis Railroad joins the track of the Chicago, Alton and Saint Louis Railroad. The latter continues in a southeasterly direction across the bottom of the high lands. The former, using what was formerly part of the line of the Chicago, Alton and Saint Louis Railroad, reaches the river-bank at a point about 1,300 feet above the bridge; it continues along the river for about 1,800 feet to the old transfer landing, where the cars of both roads were transferred across the river before the building of the bridge. The Quincy line from this point curves to the right and crosses the bottom-land in a northeasterly direction to the bluffs. The Sny Carte Levee joins the embankment of this line at a point about 1,200 feet from the river. The levee in this part is from 6 to 10 feet wide on top, with varying side slope of from 1 on 1 to 1 on 2. From this junction to a point on the embankment of the Chicago, Alton and Saint Louis Railway, some distance below the bridge, the railway embankment serves as a part of the Sny Carte Levee.

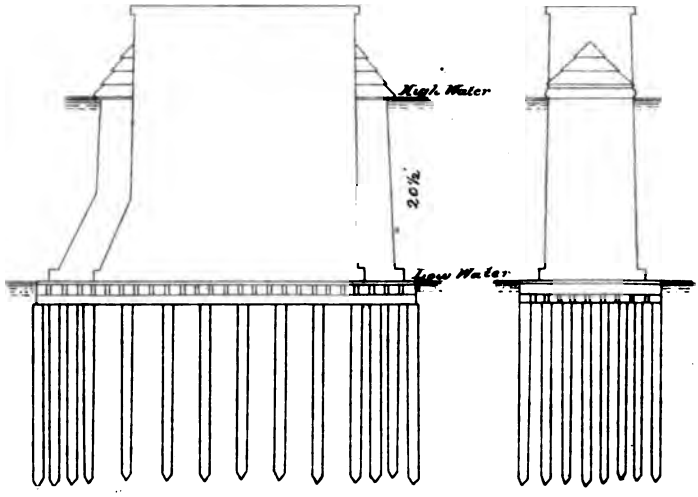
Substructure.—The piers of this bridge are of masonry, the stone having been obtained from the neighboring bluffs. The abutment on the right bank rests upon piles driven to the bed-rock, which is about 14 feet below low water. It has curved wing-walls, with steps and parapet of hammer-dressed stone. This abutment is 21 feet long and 4¼ feet wide. The piles were prepared for the masonry by laying concrete around and over the heads of them. The right rest-pier is 9 feet wide under the coping and about 25 feet long, with a batter of one-half inch to the foot rise. The upper and lower ends are triangular, the sides of

Louisiana , Mo.

ELEVATIONS OF PIER 10.

Scale of Feet





AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS.)

which make an angle of 45° with the sides of the piers, and are at right angles at their intersection, which forms the cut-water. These triangular ends commence immediately below the band or dressed course, which is at highest water-mark. These starlings are finished with sections of cones above the band course. The slope of the upper end of the piers is increased to six inches to the foot, from a point 10 feet below high water to the offset course. The starlings and band course are hammer-dressed. This description applies to all the piers in the river except the pivot. (See Diagram E′.) They are alike in form, and vary only in width, the rest-piers being one foot wider than the others. The foundation of the pivot-pier is of piles driven to bed-rock, as are those under the right and left rest-piers; they were sawed off level with the bottom of the river, and riprap placed around their heads. The masonry was built in water-tight caissons and lowered to the bearing-piles. The bottom of the caissons was a grillage of oak timber, 12 inches by 12 inches. The masonry of the pivot is 39½ feet in diameter on top, with a batter of about one-half inch to a foot. The piers to the left of the draw rest upon piles driven about 20 feet into the sand, and are cut off level with the bottom of the river at that time. The masonry, which was about 2 to 3 feet below low water, rested upon a grillage. The draw-rests are cribs of oak timber below low water mark; the sides above are of oak timber, below low water mark; the sides above are of oak plank, triangular in plan; the whole filled with riprap and resting on a bed of riprap. Above the upper draw-rest is a detached ice breaker, built in the same form and of similar material; it rises only to high water. Between the ice-breaker and the upper draw-rest are four clusters of piles to serve as fenders for boats. Between the guard-rests and pivot are pine floats built of 8 sticks on each side, 4 deep, and 2 wide; these are connected by ties and braced by diagonals. These floats are supplied with posts supported by knees, to act as fenders in snubbing-posts for boats. Above the right rest-pier is a fender which extends 500 feet, flaring on a curve, so as to be 50 feet from the prolongation of the pier at its upper end. This fender has a triangular starling composed of piles driven close together, and filled with stone to about 8 feet above low water. The main part of it is about 16 feet wide, composed of two rows of piles tied across it, each set being about 12 feet apart. On both sides they are connected by wall-strips, one near low water and one some 10 or 12 feet above. On the channel side planks are spiked vertically, close together. Inside of the fender are 16 clumps of piles, with chains and rings attached, for boats to attach to if necessary. The side toward Noix Creek is not planked. The fender piles are sustained by riprap thrown inside, to which has been added much drift-wood from Noix Creek. It is not of proper construction and has sustained much injury. The requirements of the board of engineers have not been met.

Superstructure.—The superstructure is of wrought iron, except in some minor parts. The bridge over Noix Creek, in the Missouri approach, was built by the American Bridge Company of Chicago; it is 140 feet long. The two long spans and the draw-span of the main bridge were built by the Kellogg Bridge Company of Buffalo, N. Y. The draw-span, at the time of its erection, was the longest in this country (the draw over the Raritan River, New Jersey, erected since, is 472 feet long); its width from center to center of trusses is 18 feet; height of truss at ends, about 31 feet, out to out, and at the center of truss about 40 feet. At 19 feet above the rails, in each panel except the end ones, are longitudinal and transverse braces between the posts and diagonal ties. The posts are of two channel-beams connected by an I beam; these are 12

inches deep in the center, decreasing to 6 inches at the ends. At the center are two inclined posts outside of the regular pair, which serve to carry a portion of the weight to the outside of the turn-table. The upper chord for two panels each side of the center is composed of 4 links; in the next 7 panels toward the end it is composed of links and channel-beams and plates. The ties are rectangular bars; the counter-ties, round rods. All have swivels or turnbuckles for adjustment. The ties and counter-ties extend across two panels. The floor-beams are in pairs, one beam each side of the posts. The 250-feet and 225-feet spans are 31 feet high, the same as the draw at its ends; their width is 14 feet inside trusses and 20 feet outside. The posts of these trusses are composed of two channel-beams connected by an I beam. The ties are of rectangular bars, with eyes through which the pins pass; they are not provided with means of adjustment. The counter-ties are of round rods with swivels or turnbuckles for adjustment; these ties cross two panels. The short trusses were built by the Keystone Bridge Company; they are 20 feet high, with about the same width as the long spans. The diagonals of these spans extend across but one panel. The draw is turned by a steam-engine placed on the turn-table outside of the truss. The usual time required to open and close the draw is from three to four minutes.

Accessory works.—A dike 2,500 feet long, starting from the Illinois shore, about 4,500 feet above the bridge, with its lower end 1,400 feet from the left bank, was built for the purpose of deepening the water between the steamboat-landing and the draw-openings. This was built by the bridge company under requirement of the board of engineers. It is built of brush, with riprap to hold it in place, and a few piles to strengthen it in deep water. At the time of our examination, in 1876, with the water 4.8 feet above low water, it was for the most part submerged.

INFLUENCES UPON NAVIGATION.

The current was measured by us October 12–13, 1876, when the water was 4.8 feet above low water. The form of the sand bar above the bridge was determined at the same time. The conditions can only be appreciated by an examination of the map, but a general description will be attempted. Alongside of the accessory dike built from the left bank was a large sand bar extending below it to within about 1,900 feet of the bridge. It left a channel-way between itself and the right bank of about 600 feet in width in its narrowest part. Below this sand bar is another one, which occupies a breadth of 2,400 feet in the middle of the river. It lies directly above the bridge, and extends down to within 450 feet of the axis of the bridge. This middle-ground shoal leaves deep water on each side of it; that on the Missouri side being the navigable channel. It is only 200 feet wide where the depth exceeds 3 feet at low water.

The deep water next the Illinois shore is a pocket below the dike and is of no use to navigation. In general, the threads of current on approaching this bar spread out toward each shore and converge as they approach the bridge, everywhere moving in curves until the bridge is passed. The currents make various angles with the axes of the piers, and are scarcely parallel with them in any part of the bridge. The only approach to parallelism is for a short distance in the right draw-opening, where it is confined between the upper guard-rest and the extension of the right rest-pier. The only-opening that could then be used by either rafts or boats was the right draw-opening, and the approach

to this from above was along the right bank to within about 1,000 feet of the bridge, from which point they approached the opening at an angle, because of having to move to the left about 500 feet. The spans to the left could not be used because of the middle-ground bar. We have here an example of a bridge with the widest draw-openings on the Mississippi River, being one of the most difficult to pass, and furnishing but one practical opening for anything. In high stages the shape of the shores and bed are such that the flow through the draw cannot be much different in direction, but at this time the dike and bars above were submerged, and the flow was more direct through the spans to the left of the draw, making it then the main channel of the river. At the time of the high water in 1876, the first very high water since the building of the bridge, the increased velocity due to the contraction by the bridge scoured out the bottom, particularly under the short spans next to the left bank. This deepening was discovered by those in charge of the bridge. They at once commenced to place riprap about the piers and along the axis of the bridge. This was being done in October, and our examinations showed that nearly the whole bottom between these piers was covered with riprap, and about the piers it appeared above water. The depth between the piers on the axis of the bridge was from 22 to 31 feet, and below the bridge the depth increased from 50 to 57 feet within 150 feet of the piers. The bottom of the piles on which the piers rested were only 27 to 30 feet below the surface of the water, so that the bottom had scoured out below them on three sides of the piers. Notwithstanding their efforts (without any considerable rise in the river), the second pier from the left abutment disappeared on the night of November 6, carrying with it two spans of the bridge. This shows that riprap protection against scour is not efficient when thrown from the bridge. The effect, indeed, is to prevent scouring where the stone falls; but in this case the danger was from the hole made below the axis of the bridge, which the stone did not reach, and which hole finally became so enlarged as to ingulf the whole mass situated above it. To prevent scour in such instances, boats are required from which the stone can be thrown directly into the place where the material is being removed. The effect of the dike built from the left bank has not been what was expected, and the depth of water below, near the left bank, has increased. This is probably owing to the material in the left bank being much finer than on the right, and it does not seem an unreasonable apprehension that if this dike should be carried away at time of high water the navigable channel might take down the left bank, leaving the draw-openings impassable at low water. The location of the bridge just below an important landing, as in the case of Burlington, is also objectionable.

ALTERATIONS TO LESSEN OBSTRUCTIONS TO NAVIGATION.

The great narrowing of the water-way by embankments at this bridge forms an exceptional case, and it was a part of the original design. When this plan was submitted to me in May, 1873, I made no objection to this feature of it, but said:

> All experience, on this point, on the Mississippi shows such contraction in width is compensated for by deepening until the area of section and mean velocity are the same as before.

This could not be true if the bridge was built at low water and protected by riprap from scour at high stages. After any such contraction, time should be allowed for succeeding high waters to effect the enlarge-

ment before any obstruction is placed in it; not only should time be allowed for this, but the river for a mile or more above should be narrowed and the banks rectified, so as to gradually bring the conditions of the natural river to those at the proposed bridge. This was the course pursued at Saint Louis, to which reference was made by me; there the contraction and rectification of the banks extended through considerable distance, and was gradually effected in the course of a number of years. Such sudden narrowings, as at Louisiana, with riprap protections to prevent scour, produced very abnormal conditions of engorgement, and the want of proper controlling works above left us without the means of giving permanence to the directions of the currents or the position of the channel. The only thing to do is to supply what has been omitted. In the first place, it is certain that if we do not deepen the section at the bridge to an extent too great for the safety of the present structure, we must widen the water-way. In the modifications which I propose, the Noix Creek span is given to that stream exclusively, and will not be taken into the following consideration of increasing the section of the bridge.

The present section is at low water 1,750 feet wide, excluding the piers; depth, 10½ feet; area of section, 18,200 square feet; volume, 47,000 cubic feet per second; and a mean velocity of 2.48 feet per second.

It is proposed to increase this width by removing a portion of the embankment on the Illinois side, and by building two spans of 250 feet each in the clear; this will increase the low water width to 2,250 feet.

We shall then have a new section with:

Width	2,250	feet.
Depth	10½	feet.
Area of section	23,625	square feet.
Volume	47,000	cubic feet per second.
Mean velocity of about	2	feet per second.

At high water the present conditions are:

Width	1,750	feet.
Depth	30½	feet.
Area of section	53,375	square feet.
Volume	480,000	cubic feet.
Mean velocity	9	feet per second.

With proposed increased width:

Width	2,250	feet.
Depth	30½	feet.
Area of section	68,625	square feet.
Volume	480,000	cubic feet per second.
Mean velocity	7	feet per second.

To remove and prevent the reformation of the sand-bar in the middle of the river above the bridge, and to give proper direction to the current, it will be necessary to build new banks and cross-banks running out from the present shore-lines to them. The proposed new shore on the right bank will be on the prolongation in nearly a straight line of the extension of the right rest-pier up to the landing at Louisiana. This new bank will entirely shut off Noix Creek. If it is necessary to use the mouth of this creek for any purpose it must be done by coming into it from below the bridge.

The line of the proposed new left bank will extend from the proposed new abutment in a line parallel with the new right bank up river about 4,200 feet. The distance between these banks is about 2,400 feet. The cross-banks should be from 300 to 600 feet apart, as experience shows necessary. The work should be begun by building these cross-banks. These should be commenced at the shore, and extended outward by

laying down mattresses and weighting them. The bottom layer should be put in over the whole distance at once to prevent scour at the ends, and they should be raised at such rates as the observed effects call for. The portion of the present wing-dam above the bridge, between the proposed new banks, should be removed. It is unnecessary to enter into details of this operation here. The frequent failure of these cross-banks or jetties in this country has been due to their being placed too far apart. There may be no necessity of building the new left bank more than to put a T at the end of the cross-banks; and their heights there need not exceed the height of the present bottom land. The new longitudinal bank on the right side should, however, extend 4 feet above the highest water, so as to produce no cross-currents into or out of Noix Creek.

Similar regulation of the river to that proposed here is used at Kinlenburg Bridge, in the Netherlands. The difficulty of making a suitable draw-bridge at this point will probably lead to the adoption of a high bridge in its place.

Sheer-booms.—The board of engineers recommended as an immediate alleviation of the difficulties experienced in passing rafts, that the bulk-head in extension of the right rest-pier be continued up river at least 500 feet, and this line extended 820 feet further by a fixed boom, its upper end 300 feet from the shore at ordinary low water.

HIGH BRIDGE.

A high bridge at this place would have to be placed 57 feet above high water. It would have an easy approach from the right bank and a high approach on the left bank. It should have at least three high spans, with clear openings of not less than 300 feet each.

SAINT LOUIS ELEVATED RAILWAY AND HIGHWAY BRIDGE.

(Opened for travel in July, 1874.)

Authority.—This bridge was built under provisions of sections 11 and 12 of the act approved July 26, 1866, and act approved July 20, 1868.

DESCRIPTION OF THE RIVER AND VALLEY AT THE LOCALITY.

The Mississippi has been subjected to great artificial contractions at Saint Louis, beginning in 1838 when dikes were commenced to prevent the enlargement of the channel east of Bloody Island and improve the one on the other side. These works were added to from time to time, and in 1850 a low water stone dam was built across the channel east of Bloody Island, which, however, was afterward carried away. In 1852 the present high water dam connecting Bloody Island with the Illinois shore was built and made a highway. Prior thereto this channel had become so filled up that water did not run through till the river was 13 feet above low water. (See report of Col. W. E. Merrill, major engineers.) The site of Saint Louis is mainly above overflow. The shore in places is of rock. Considerable portions of the river front have been graded, sloped, and paved with stone. Bloody Island, now East Saint Louis, has been partly raised above overflow, and the river front also sloped and paved.

The low lands in Illinois known as the "American Bottom," about 6 to 8 miles wide, are protected from overflow. The whole volume of the river is therefore confined to a narrow channel about 1,200 feet wide at

low water and 1,900 feet at high water. The slope of the water surface, at both high and low water, is on an average about .65 foot per mile. The maximum velocity and volume have not been determined. The ordinary high floods are about 35 feet; the greatest known 41½ feet above low water.

The city directrix is 33½ feet above low water. The scouring in time of floods and ice-gorges is very great. The bed-rock lies about 90 feet below the surface of low water on the Illinois side, and probably underlies the whole "American Bottom" at about that level. Surveys were not made by me at this place, all the important information to be obtained in this way having been determined by other officers of engineers. The wide spans and piers parallel with the current give ample space on the water, but the headway is insufficient to allow the large steamboats to pass it at high water. (See discussion in Chapter III.)

DESCRIPTION OF THE BRIDGE.

The information available for a description of this bridge is contained in a report of the engineer-in-chief in 1868, and the modifications of it given in his report in 1870, together with the discussions in regard to it, printed in the transactions of the American Society of Civil Engineers. It is probable that we shall, in due course of time, have a full account of the bridge in detail, and of all the operations connected with it; but it has such an important relation to the navigation of the Mississippi that it is thought best to attempt to give a general idea of it here. The abutments are placed on the margin of the water at ordinary low stage, with two piers in the channel-way. The three spaces thus left are spanned by circular segment arches. The middle one has a chord of 515 feet and versed sine of 47½ feet. The lowest part of the arch at the springing line is 7½ feet above the city directrix, or at the level of high water of 1844. The crown of the arch is therefore 55 feet above the city directrix. The chord of the side spans is 497 feet, and the versed sine 43 feet 10 inches. The springing lines at the abutments are 18 inches lower than at the piers, so as to lower the crown about 9 inches, leaving the height at that point 50½ feet above the directrix.

Mr. Theodore Cooper says (Trans. Am. So. Civ. Engrs., vol. iii, p. 239):

> Each span is composed of four arched *ribs* spaced respectively 16½, 12, and 16½ feet apart from center to center (Figs. 3 and 4). Each of these ribs is composed of two lines of tubes (called the upper and lower *member* according to their position), spaced 12 feet apart between centers of the tubes. The several tubes are about 12 feet long. The upper and lower members of each rib are connected together by a system of triangular bracing. The first or skew-back tubes of each member are rigidly fastened (screwed into) the large wrought-iron skew-backs, which in turn rest upon the bed-plates set into the masonry, the whole being firmly anchored to the piers or abutments by large steel anchor-bolts. The several tubes forming one line or member are rigidly connected at their ends by grooved couplings (Fig. 5), carefully fitted to grooves cut on the ends of the tubes. The couplings are made in halves with flanges for bolting them together. Through the center of each coupling and the ends of the tubes passes a taper pin-hole for the steel pin, upon which the braces and cross-stays are attached. All joints were made as nearly perfect as the best mechanical appliances would permit.

The section of the tube is a circle. Each tube has an envelope of steel one-quarter of an inch thick. There are six steel staves in each tube. Their thickness is as follows, beginning at the springing lines: Staves in first tube, $2\frac{1}{8}$ inches; second tube, $1\frac{7}{8}$ inches; third, $1\frac{5}{8}$; fourth and fifth, $1\frac{7}{16}$ inches; thence to the center $1\frac{3}{16}$ inches.

The two lines of tubes, forming a single vertical rib, are united together and braced by a single triangular system of vertical bracing,

formed of flat bars of wrought iron secured to the tubes by steel pins passing through the center of each coupling. Each individual tube is straight, the curvature of the rib being accomplished at the junction of these individual members.

In the report of the Chief Engineer, 1868, pp. 32–33, it is stated that—

A granite course 8 feet in thickness will be laid through the channel-piers and in the abutments, to receive the skew-backs or heavy cast-iron plates against which the ends of the arches will rest.

In the report for 1870 the arched ribs are so modified that there are but two tubes in each 12 feet apart from centers, instead of 9 feet as first designed. The granite course was probably increased to a corresponding thickness. According to the drawing in the report for 1870 the thickness through the piers at the springing line of the lower tubes is about 31 feet, so that the distance from abutment to abutment at the springing lines is about 497 + 31 + 515 + 31 + 497 = 1,571 feet.

The batter of the masonry appears on the drawings about 12 upon 1, and as the springing lines of the center span are 41 feet above low water (besides there being an offset of 1 foot), the width of the center span at low water is reduced by about 9 feet; or is about 506 feet clear of masonry. The side spans are reduced by about the same amount at low water, so that these spans are 488 feet in the clear at the level of low water. The drawing shows the levee occupying about 30 feet of this shore-span, so that there is more space at low water than the river-banks afford.

Roadways and lateral bracing.—The roadways are supported by vertical wrought-iron posts of "cruciform section" rising over the upper tubes at the points where they are united with the lower ones by the triangular system of bracing. The two center arched ribs in each span are placed 12 feet apart from center to center. These two arches are thoroughly braced against lateral motion, both at the upper and lower tubes. The outside arches are 16½ feet from the middle ones. The level of the railway in the middle portions of the span is placed near the lower tube, and this compelled a modification of the bracing used in the middle arches, wherever the upper arch rose above the railway-track. At these portions the lateral bracing is confined to the upper and lower roadways.

In the report for 1868 it is stated that—

The upper roadway is 34 feet wide between the foot-walks. The latter are each 8 feet wide, making the bridge 50 feet wide between railings.

Captain Eads states (in Trans. American So. Civ. Engrs., vol. iii, p. 322) that the cost was increased by widening 4 feet.

The railway passages below the carriage-way will each be 13 feet 6 inches in the clear and 18 feet high, and will extend through arched openings of equal size in the abutments and piers. The railways will be carried over the wharves on each side of the river on five stone arches, each 26 feet wide, and will be inclosed throughout this distance by a cut-stone arcade of twenty arches supporting the upper roadway. After passing over those stone arches the railways will be carried through the blocks between the wharf and Third street on brick arches into the tunnel at Third street and Washington avenue. Over the intervening streets they will be carried on wrought-iron trusses. On the Illinois shore the railways will curve off to the north and south immediately after crossing the last one of the stone arches, and, with a descending grade of 1 foot in 100, extending about 3,000 feet, and supported on trestle-work part of the way, they will reach the grade of the railways in East Saint Louis. The carriage-road will begin to descend with a grade of 5 feet in 100, at the eastern end of the bridge, immediately after the railway-tracks curve away from the latter, and will conform at Third street, in East Saint Louis, to the grade of that street. On the Missouri side the carriage-way will be continued over the railway-tracks from the bridge to Third street on a level grade.

The railway grade between the two abutments is a little less than 1 in 100. The railway gradients of the approaches are 1 in 100, and some trouble has been experienced in the crawling of the track under the action of the driving-wheels of the special locomotives employed, as has been the case with other bridges with a grade of 1 in 100.

The superstructure was erected by the Keystone Bridge Company, under the superintendence of Mr. Walter Katté. It was done without false works, by suspending the tubes from the towers with tie-rods, and employing temporary anchorages on the banks of the river.

Foundation of the piers and abutments.—The foundations all rest upon the bed-rock of the river. The Saint Louis abutment with much difficulty was placed, by means of an ordinary coffer-dam, upon the bed-rock, about 13 feet below low-water mark. The others were sunk to the bed-rock by means of inverted caissons and the plenum pneumatic process. Great ingenuity, boldness, and skill were displayed in this work, which succeeded with some loss of life, inseparable from the great air-pressure necessarily employed. The depths below extreme low water to bed-rock were, for the Saint Louis pier, 58 feet; for the east pier, 86 feet; for the east abutment, 94 feet. The water was rarely less than 5 feet above extreme low water, and it was important in economy of time to work with the water as much as 18 feet above low water. It is probable, however, that this increased pressure could not be generally endured when the pier-foundations had approached the bed-rock at the greatest depth. The foundations of the shore approaches in the Saint Louis side were placed on rock. On the Illinois side they rest on piles cut off at about the level of low water. Considerable difficulty was found in the yielding nature of the silt which had filled in the old channel east of Bloody Island, and only the lightest trestle approaches could be readily built there.

Masonry.—Most of the stone used is the magnesian limestone of Grafton, but there is a course of ashlar of granite in all the parts exposed to running ice from 4 feet below low water up to the highest floods.

Loads.—The arches have been designed with sufficient strength to sustain the greatest number of people that can stand together upon the carriage-way and foot-paths from end to end of bridge, and at the same time have each railway-track below covered from end to end with locomotives.—(Report of Engineer-in-Chief for 1868, p. 33.)

On next page of this report it is stated:

The weight of the three spans and the maximum load they are designed to bear is 7.2 tons per linear foot.

On the diagrams of strains accompanying this report the weight of the structure is taken at 1 ton per linear foot per rib, leaving but 3.2 tons for the moving or live load. In considering the moving loads in devising the new Rock Island bridge, I was advised to allow 2,500 pounds per foot for a single-track railroad, and 100 pounds per foot for each square foot of common road and sidewalk. This allowance would have required 5,000 pounds per foot for a double-track railroad and 5,000 pounds per foot for a highway 50 feet wide, or a moving load of 5 tons, being as 25 to 16 over that provided for here. Both tracks filled with engines would weigh about 5,000 pounds per foot, leaving out of the 3.2 tons, or 6,400 pounds live load, but 1,400 pounds per foot for the upper roadway packed with people, which would be only 28 pounds per linear foot. This is evidently too small an allowance.

The bridge designed by the convention of civil engineers, in the year 1867, was for a single-track railway, moving load 2,184 pounds; two wagon-ways, 14 feet wide each, moving load 100 pounds per square foot,

or 2,800 pounds per linear foot; two sidewalks, 8 feet wide each, moving load 70 pounds per square foot, or 1,120 pounds per linear foot, making a total moving load of 6,104 pounds per linear foot, which is almost as much as the present bridge allows for wider common roadway and one more railway.

Mr. Eads, in his discussion in the American Society of Civil Engineers, page 322, states the cost as follows:

Masonry—abutments, piers, tools and machinery	$2,364,452 26
Superstructure, excluding approaches	2,234,655 42
General items of engineering and contingent account	400,000 00
Cost, excluding approaches	4,999,107 68
Cost for everything, including approaches, salaries, rents, engineering, steam and street railways, gas and water-pipes, all of its approaches, losses by failure of contractors, extra compensation and bonuses to expedite work (but excluding tunnel and land damages)	6,680,331 47
Additional cost of bridge, consisting almost wholly in items of discount, interest, and commissions on bonds, charters, legal expenses and similar expenditures, including $1,086,000 for real estate and right of way	6,000,000 00

The opinions of engineers generally are unfavorable to this form of bridge.

(1.) It is of a form that interferes too much with navigation. (Report of Army Engineer Board.)

(2.) It is not considered a good pattern for economy.*

(3.) It is subject to great strains due to temperature.*

(4.) It is difficult to calculate the strains upon different parts and apportion the dimensions of parts.*

This bridge has had a large influence upon the question of bridging navigable channels which is shown in the next chapters to this report. (Chapter V.)

Tabulated statement of bridges on the Mississippi between Saint Paul, Minn., and Saint Louis, Mo., authorized but not built.

Bridges.	Act approved—	Remarks.
HIGH OR DRAW BRIDGES.		
Red Wing, Minn	June 10, 1872	
La Crosse, Wis	Feb. 21, 1868	
Savanna, Ill	Apr. 1, 1872	
Clinton, Iowa	Apr. 1, 1872	By act approved June 6, 1874, may be built as a pontoon bridge.
Muscatine, Iowa	Apr. 1, 1872	
Fort Madison, Iowa	May 25, 1872	
Warsaw, Ill	May 17, 1872	Authority expired by limitation.
Quincy, Ill	May 17, 1872	
PONTOON BRIDGES.		
La Crosse, Wis	July 6, 1876	Highway bridge.
Dubuque, Iowa	Mar. 3, 1873	Do.
Clinton, Iowa	June 6, 1874	Railway bridge; it may be built under this act or under the act of April 1, 1872.

* Discussion in Am. Soc. Civ. Engrs.

CHAPTER V.

GENERAL HISTORY OF BRIDGING THE NAVIGABLE WESTERN RIVERS IN ITS RELATION TO THE LAWS; TO THE DECISIONS OF THE UNITED STATES COURTS; TO THE DEBATES IN CONGRESS; TO THE OPINIONS OF EMINENT ENGINEERS, ETC., GIVEN IN A CHRONOLOGICAL ORDER.

HISTORY OF THE BRIDGE ACROSS THE OHIO AT WHEELING—HISTORY OF THE FIRST BRIDGE ACROSS THE MISSISSIPPI AT ROCK ISLAND—ABSTRACT OF DEBATES IN CONGRESS PRECEDING THE AUTHORIZATION OF BRIDGES ACROSS THE MISSISSIPPI RIVER—ABSTRACT OF DEBATES IN CONGRESS LEGALIZING THE BRIDGE ACROSS THE MISSISSIPPI AT CLINTON—HISTORY OF BRIDGING THE MISSISSIPPI AT SAINT LOUIS—QUOTATIONS FROM DECISIONS OF THE UNITED STATES SUPREME COURT FOR INJURIES SUSTAINED AT THE SAINT PAUL RAILWAY DRAW-BRIDGE—MEMORANDUM UPON BRIDGING THE OHIO RIVER SUBSEQUENT TO THE WHEELING BRIDGE CASE—MEMORANDUM UPON MISSOURI RIVER BRIDGES—ABSTRACT OF LAWS FOR BRIDGING THE OHIO, MISSISSIPPI, AND MISSOURI RIVERS.

Introductory remarks.—The information presented in this chapter consists of notes, &c., obtained by reading the Statutes at Large; the decisions in the United States courts; the debates in Congress, and the reports of engineers, together with correspondence in regard to points of interest upon which information was wanted. This was done at first for my own use, but it appeared to me when this report was about finished that it might contain information of value to others, who may have to consider this subject of bridging navigable waters, either as engineers or law-makers. I have therefore thrown these notes together in a general chronological order, and for want of a more appopriate term have designated it as a general history of the bridging of the navigable western rivers, although it cannot but fail to rise to the dignity which the name implies. In chapters II, III, and IV of this report I have treated the subject almost purely in its relations to engineering and navigation. The present chapter, in a measure, exhibits the relations which these things have held to other interests.

HISTORY OF THE BRIDGE ACROSS THE OHIO AT WHEELING.

The first bridge over important navigable western rivers was that across the Ohio River at Wheeling, built in 1848–'49. It occasioned a suit for injunction which came before the United States Supreme Court, the reports of which give us all the information we could desire up to that time. The whole subject is here so thoroughly considered that it is certain that no reasonable view could be taken of the subject at that time that was not then presented and discussed. It naturally furnishes us a good point of beginning.

From these reports we learn that the National Road as it was often called, reached the banks of the Ohio at Wheeling where the passage between Wheeling and Zane's Island by ferry was found dilatory and precarious by day, and ordinarily useless at night, being frequently impassable on account of ice, and that a bridge being much desired by the people of Ohio and Virginia, acts were passed in 1816 by both those States, authorizing a bridge across the river at Wheeling, but which provided that if such bridge should be so constructed as to injure the navigation it should be treated as a public nuisance, and be liable to abatement as other public nuisances. Ten years were allowed for the completion of the bridge.

By an act of Virginia in 1836, certain facilities for the reorganization of the bridge company were conferred, and by the consent of Ohio the time was extended ten years longer. This company constructed a continuous truss-bridge from Zane's Island to the Ohio or western shore.

In March, 1847, the legislature of Virginia passed an act reviving and continuing certain parts of the former acts, and providing for the reorganization of the corporation "with power to erect and keep a wire suspension-bridge on and from Zane's Island to and upon the main Virginia shore or bank at the city of Wheeling."

This act contained the proviso—

That if the said bridge shall be so erected as to obstruct the Ohio River, as navigated in the usual manner by such steamboats and other craft as are now accustomed to navigate the same, when the river shall be as high as the highest flood therein heretofore known, then unless upon such obstruction being found to exist, such obstructions shall be immediately removed or remedied, the said last mentioned bridge may be treated as a public nuisance and abated accordingly.

A petition for a law authorizing a bridge at Wheeling, was before Congress in 1836, and urged during both sessions of the Twenty-fourth Congress without success. The matter was reported upon by Lieut. George Dutton, Corps of Engineers, and Lieut. John Sanders, Corps of Engineers (House Doc., No. 993, Twenty-fifth Congress, June, 1838).

They presented a plan for a suspension-bridge across the Ohio River, having for its basis a strict regard to the rights of navigation. * * * This plan proposed a span of 500 feet in width and the height of the highest chimney then known, and in order to provide for any change or improvement in steamboats, the floor of the bridge was to be movable so as to allow the passage of boats. [Argument of Mr. E. M. Stanton, before United Sates Supreme Court, Howard, vol. xiii.]

It was stated that the highest flood, that of February, 1832, was extraordinary and rose 44½ feet above low water at Wheeling, that the highest usual flood does not exceed 38½ feet, but will not average 35 feet for spring floods nor much exceed 29 feet.

It was claimed by the bridge company—

That for all useful purposes, the pipes of steamboats need not exceed 47 feet above the water, and that if the draught was not sufficient, blowers might be added. That chimneys might have hinges on them so that they could be lowered.

The steamboat-men claimed that the existing heights of chimneys, in some cases 84 feet 7 inches above the water were necessary; and that their large diameter, over 5 feet in some cases, and their weight (the two together, in some cases, weighing 4 tons) made it impracticable to lower them.

Steamboats of the largest class then running to Pittsburgh were on an average 230 feet long and over 50 feet wide. The pilot-houses stood 48 feet above the water.

The bridge from Wheeling to Zane's Island consisted of a single span of 1,010 feet from center to center of the supporting towers, the height of which was claimed to be 90 feet at the eastern abutment, 93½ feet at the highest point, and 62 feet at the western abutment, above low water.

The bridge was begun in 1848. While it was in the earlier stages of construction notice was served upon the company, of a suit to enjoin them July 28, 1849. This suit was brought in the United States circuit court sitting in Philadelphia. Mr. Justice Grier, one of the judges of the United States Supreme Court sitting, transferred the case on August 16, 1849, to the Supreme Court, "because the question of the plaintiff's right to prosecute this is new and involves the jurisdiction of the court."

On January 11, 1850, the legislature of the State of Virginia passed an act "to the effect that the suspension-bridge as erected was of a lawful height and in conformity with the intent and meaning of the proviso in the enabling act passed in 1847."

The first report of the case, in the United States Supreme Court, was of the hearing at the January term in Washington in 1850, and is reported in Howard, vol. IX, pp. 647–659, Pennsylvania *v.* Wheeling and Belmont Bridge Co. et al. On May 29, 1850, the court ordered the cause to be referred to the Hon. R. Hyde Walworth, ex-chancellor of the State of New York, as a commissioner of the court, thus far affirming the question of jurisdiction, to which Mr. Justice Daniels dissented.

The commissioner was to take such further proofs in the cause as the counsel for the respective parties may see fit to produce before him. The commissioner was also directed, if the bridge should appear to be an obstruction to the free navigation of the Ohio River, to state:

> What changes or alterations in the construction and existing condition of the said bridge, if any, can be made consistent with the continuance of the same across said river that will remove the obstruction to the free navigation.

The commissioner was to report at the next stated term, December, 1850.

At the December term, 1850, on the 13th of that month, the commissioner's report was received, and the court ordered that the case be continued to the next term, with leave to each party to file exceptions to the commissioner's report on or before the first Monday of July, the exceptions to stand for argument on the second Monday in December, 1851. If no exceptions shall be filed by either party, then the case to stand for final hearing on the day last mentioned. (See Howard, vol. 11, pp. 528, 529.)

The report of the case at the December term of 1851 is given in Howard, vol. 13, pp. 518–628.

The printed report (more than 700 pages) of the commissioner, with the report of his engineers, and the evidence taken, was presented. Copies of this report are rare. It was printed by George White, at Saratoga Springs, N. Y., in 1851. His decision was that the bridge was an obstruction to free navigation of the Ohio by vessels propelled by steam, but not by any propelled by sail. That the bridge should be changed by raising "the cables and flooring in such manner as to give a level headway at least 300 feet wide over a convenient part of the channel of not less than 120 feet above the zero on the Wheeling water-gauge." As built, the highest point was about 92 feet above low water level, and it descended each way toward the shores 4 feet in 100 feet, so that, taking the highest point as a center of the highest space, 100 feet wide, it is at its extremities only 90 feet above low water.

After a full hearing from learned counsel on both sides, a majority of the court decided that—

> The bridge obstructs the navigation of the Ohio, and that the State of Pennsylvania has been and will be injured in her public works in such manner as not only to authorize the bringing of this suit, but to entitle her to the relief prayed for.
>
> * * * * * * *
>
> And on a full view of the evidence we are brought to the conclusion that an elevation of the lowest parts of the bridge for 300 feet over the channel of the river, not less than 111 feet from the low-water mark, will be sufficient, the flooring of the bridge descending from the termini of the elevation at the rate of 4 feet in the 100 feet in width, and will enable those whose chimneys are 80 feet high to pass under the bridge when the water is 30 feet deep from the ground, leaving the tops of the chimneys 2 feet below the lowest parts of the bridge. If this or some other plan shall not be adopted which shall relieve the navigation from obstruction on or before the 1st day of February next (1853), the bridge must be abated.

We do not deem it necessary to provide against the floods, which seldom occur, and which, when at the highest, overwhelm the lower parts of the cities and towns on the banks of the Ohio, and necessarily suspend, for a short time, business upon the river.

To this decree Mr. Chief Justice Taney and Mr. Justice Daniels dissented, denying jurisdiction in the absence of more specific legislation by Congress, and for other reasons.

Upon the opinions being pronounced, the counsel for the defendants suggested to the court that some other change might be made than that directed, which would be less expensive to the bridge company and equally satisfactory to the public, and submitted four alternative propositions for consideration. These the court received, and on March 1, 1852, directed Mr. William J. McAlpine, "the engineer, who acted under the commissioner," to report upon them. This report was made May 8, 1852, and is given in the Howard report, vol. 13, pp. 615–621, and made the subject of further argument, which, however, is not reported.

Mr. McAlpine reported that two sliding draws might be constructed across the western channel, over which there was an ordinary low truss-bridge in continuation of the suspension-bridge across the main channel, giving clear opening of 200 feet, at an expense not so great as raising the suspension-bridge according to the decree of the court; that clear draw-opening of 300 feet might be made by rebuilding this part of the bridge, but that it would cost more than raising the suspension-bridge.

The court adopted his view that—

A draw can be constructed in the wooden bridge over the western channel of the river which will, under ordinary circumstances, offer a safe and convenient passage for the largest class of boats which ply from Pittsburgh, having chimneys 80 feet high.

A draw of 200 feet was proposed, and one less than that would not answer the public demand.

Without changing the former decree, it was left an open question for the bridge company to adopt this change instead of the other before the 1st day of February, 1853, "on which day the plaintiff may move the court on the subject of the decree, and if the proposed alteration in the western channel which being before the court, will enable them to act in the premises as the law and equity of the case may require."

Mr. Chief Justice Taney and Mr. Justice Daniels dissented, not only as to the jurisdiction of the court, but thought a draw giving a clear width of 100 feet at the utmost would be ample. The continuation of the case of this bridge is in 18 Howard, pp. 421–463.

On August 31, 1852, Congress enacted—

That the bridges across the Ohio River at Wheeling, in the State of Virginia, and at Bridgeport, in the State of Ohio, abutting on Zane's Island in said river, are hereby declared to be lawful structures in their present positions and elevations, and shall be so held and taken to be, anything in the law or laws of the United States to the contrary notwithstanding.

That the said bridges be declared to be and are established post-roads for the passage of the mails of the United States, and that the Wheeling and Belmont Bridge Company are authorized to have and maintain their bridges at their present site and elevation, and the officers and crews of all vessels and boats navigating said river are required to regulate the use of their said vessels, and of any pipes or chimneys belonging thereto, so as not to interfere with the elevation and construction of said bridges. (10 Stat. at Large, 112.)

The bridge company, therefore, took no measures to comply with the decree of the Supreme Court.

In the summer of 1854 the bridge was blown down by a violent storm, and the company were preparing to rebuild it according to the original plan when the next step in the history of the case was taken.

A notice was served upon the bridge company, and pursuant thereto the attorney-general of Pennsylvania and counsel appeared before the Hon. R. C. Grier, one of the justices of the Supreme Court, at chambers, on the 26th of June, 1854, and moved for an injunction, as prayed for in a supplemental bill then exhibited. On hearing the bill and affidavits, the injunction was granted.

The writs of injunction were served, yet they proceeded to erect the bridge notwithstanding, and it was completed in November.

At the December term, 1854, the complainant filed a motion for a sequestration against the company for a contempt of court in disobeying the injunction, and a motion for an attachment against the officers personally for their contempt in disobeying the injunction.

A majority of the court were of the opinion that the act of Congress afforded full authority to the defendants to reconstruct the bridge, and the decree directing its alteration or abatement could not, therefore, be carried into execution after the enactment of this law. The motion for the attachment was denied and the injunction dissolved.

Mr. Justice McLean and Mr. Justice Grier dissented, and each gave an opinion. Mr. Justice Daniels concurred, and gave a separate opinion about the question of original jurisdiction.

There were other suits against the bridge company for damages, but all fell upon the passage of the act of Congress legalizing the bridge and the decision of the Supreme Court in regard to it. In this respect the law was regarded as retroactive.

The condition of this bridge and its effect upon navigation was reported upon by the board of engineers, composed of myself, and General Weitzel, and Colonel Merrill, Corps of Engineers, in 1870. (See Annual Report Chief of Engineers, 1871, p. 405.)

HISTORY OF THE FIRST BRIDGE ACROSS THE MISSISSIPPI AT ROCK ISLAND.

This was a railway draw-bridge, opened for travel in 1856, and torn down in 1872. It was probably the worst obstruction to navigation that any bridge ever occasioned. Happily it now exists only in history, but that history is instructive.

This bridge was built between the years 1853 and 1856, to connect the Chicago and Rock Island Railroad in Illinois with the Mississippi and Missouri Railroad in Iowa, this latter extending from Davenport to Iowa City, a distance of about 55 miles.

Authority to build.—A railroad-bridge company was incorporated by the legislature of the State of Illinois—

> To build, maintain, and use a railroad-bridge over the Mississippi River, or that portion within the jurisdiction of the State of Illinois, at or near Rock Island, in such manner as shall not materially obstruct or interfere with the free navigation of said river, and to connect by a railroad, either in the State of Illinois or Iowa, terminating at or near said point, * * * * * *
>
> *Provided*, The said company shall commence said bridge within two years, and shall complete the same within six years from the passage of this act.

This act was approved January 17, 1853, and went into effect immediately.

There was much difference of opinion as to the extent of the jurisdiction of the State of Illinois, but no one claimed it to extend beyond the center line of the deepest navigable channel between Rock Island and the Iowa shore. It does not appear that any special authorization to extend the work from the Iowa shore to this channel-line was obtained from the legislature of the State of Iowa. In the hearing of the bill

requesting an injunction to restrain the Mississippi and Missouri Railroad Company from rebuilding or adding to the piers, before Judge John M. Love, in the United States District Court, at Burlington, Iowa, in August, 1858, it is stated.

The said Mississippi and Missouri Railroad Company own the land on the Iowa shore where the said bridge terminates, and have procured the right of way and have constructed a railroad from said bridge to Iowa City, a distance of about 55 miles. That as a color of right for the establishment of said bridge and using the same. They have procured a deed of conveyance from Antoine Le Claire, the former owner of the land on the bank of the river where said bridge terminates, thereby conveying to said company the land to the center of the main channel of said Mississippi River, including the identical ground upon which said piers are built on the Iowa side of the main channel of said river.

In the answer, the defendants set up no other claim of right to build the bridge over the Iowa part of the river, so that the above quotation probably represents this feature of the right of way correctly.

Authority contested but sustained.—The route, as located, extended over the island of Rock Island, then and now belonging to the general government, and held as a military reservation, and soon after the act of incorporation by the general assembly of Illinois, in 1853, the Secretary of War directed the United States district attorney of that State to apply for an injunction. The principal point made in the bill was against the right of way across the island, and the question of obstruction to navigation only received consideration incidentally. The depositions by affidavit and argument were made before Judge John McLean, associate justice of the United States Supreme Court, at chambers, at Washington City. The opinion was delivered at Chicago in July, 1855, and the case is reported in the sixth volume of McLean's Reports, page 517. The injunction was refused and the construction of the bridge went on, and it was completed, as already stated, in the winter of 1855–'56, so that on the opening of navigation in 1856 steamboats were compelled to pass through the draw-openings of the bridge.

Injuries and suits for damages.—Serious delays and damages to vessels in passing the east draw-opening (the other being impracticable) at once began, and many rafts were broken up by the piers. On May the 6th the new steamboat *Effie Afton*, in passing the draw, was caught upon the head of one of the piers, careened over so as to upset one of the stoves on board of her, from which she took fire and was destroyed. One of the spans (they being wooden Howe trusses) was burned with her. Fortunately there was no loss of life. Many other vessels were damaged during this year.

A suit for damages against the bridge company was brought by the owners of the *Effie Afton* and tried at Chicago, Ill., in September, 1857, the Hon. John McLean, associate justice of the United States Supreme Court, presiding. The jury could not agree and were discharged.

On the 4th of January, 1858, the United States House of Representatives passed a resolution that the Committee on Commerce inquire if the bridge at Rock Island is a serious obstruction to navigation, and, if so, to report what action, if any, on the part of the government was necessary. Mr. E. B. Washburne, chairman, submitted the report April 15, 1859, printed as H. R. Report No. 250, Thirty-fifth Congress, first session. This report states that it is the opinion of civil engineers who have seen the bridge that its position is very bad; unlike any they have before seen; and that it cannot be otherwise than a very serious obstruction to the passage of boats. It states also—

That the number of passages by steamers at this point is about one thousand a year, each of them having on board, without doubt, many passengers and valuable freight.

If, as the friends of the bridge assert, the railroad interests need a bridge near that point, surely it should be constructed in the best possible manner, and so as to afford the best water-way and easiest passage for the very large number of boats passing there. We think the company have failed to do this, and that any bridge is a *material obstruction* which is susceptible of being essentially improved.

This report concludes as follows:

From the evidence presented before your committee, they cannot doubt but that the bridge, as at present constructed, is a material and dangerous obstruction to the navigation of the Mississippi River, but they believe that the courts have full and ample power to remedy any evil that may exist in that regard. At present they are disinclined to recommend any action by Congress in the premises; but whether at some future time it may not be expedient to direct the proper law officers of the government to proceed against the bridge, this committee will not now undertake to determine.

Appended to this report is an abstract of the *Effie Afton* trial; also opinions adverse to the bridge of Capt. M. C. Meigs, Corps of Engineers; General Joseph G. Totten, Corps of Engineers; Mr. Charles Ellet, jr., civil engineer; and the presidents of several insurance companies.

The bridge-piers, as first built, were very weak structures, mostly timber cribs filled with stone. They were not only temporary in the kind of material, but were not of proportions as to weight and strength to withstand the impact of ice and other floating bodies in the swift current in which they were placed, although resting on the rock-bed of the rapids. Hence it was that in 1858 it became necessary to replace and strengthen some of the piers on the Iowa side of the channel. A vigorous effort was made by the navigation interests to obtain an injunction and prevent the placing of any more stone or enlargement of the piers. The case known as Ward *vs.* The Mississippi and Missouri Railroad Company was presented and argued before the Hon. John M. Love, district judge, in the United States District Court, district of Iowa, opening at Burlington on August 19, 1858. The plaintiffs supported their case by elaborate affidavits from eminent civil engineers and skillful pilots and other navigators, to the effect that the structure was a most serious and unnecessary obstruction to navigation. The judge decided, for reasons given, not to grant the injunction.

The plaintiff immediately filed a supplemental bill, setting forth that since filing the original bill there was reason to believe the defendants were preparing to increase the obstructions by new works not stated in their answer to the original bill, and praying that they be enjoined from doing anything not set forth in that answer. The hearing upon this supplemental bill was adjourned till November 16, at the request of the defendants, they stipulating that no cribs or other structures should be placed in the river until this hearing. Report of the suit, including the testimony, was published by the Missouri Republican, and printed in pamphlet form by George Knapp & Co., Saint Louis, Mo.

At the request of certain Senators and Representatives in Congress, the Secretary of War appointed a board of engineers, composed of Capts. A. A. Humphreys, G. G. Meade, and William B. Franklin, Corps of Topographical Engineers, to examine and report upon the Rock Island bridge. Their report is dated May 9, 1859, the examination having been made in April preceding. This board considered the engineering questions, and made careful measurements of velocities, and determined the injurious effect of the piers. They reported that the bridge was not only a material obstruction, but one materially greater than was necessary. The report was printed with the report of Col. J. J Abert, Chief of Topographical Engineers, annual report of the Secretary of War for 1859, pp. 836, 837, 838, 839, 840, 841. It was the cause of the provision in the bridge laws requiring the piers to be parallel to

the current. I have, on account of its general bearing on the subject of bridging the Mississippi, inserted it here.

DETROIT, MICH., *May* 9, 1859.

SIR: The Board of Engineers organized in conformity to your letter to the honorable Secretary of War, dated March 1, 1859, for the purpose of making certain examinations upon the construction of the railroad bridge across the Mississippi River between Rock Island, in the State of Illinois, and Davenport, in the State of Iowa, has the honor to submit the following report:

The Board was furnished with copies of the letter addressed to the honorable Secretary of War by certain Senators and Representatives in Congress asking for its appointment, and the letter of the Bureau of Topographical Engineers to the War Department specifying points for the Board to examine and report upon. Copies of the maps of the survey of Rock Island Rapids, made by Capt. R. E. Lee. Corps of Engineers, in 1837, and of the survey of the same rapids, made by Lieut. G. K. Warren, Corps of Topographical Engineers, in 1853, were also furnished.

It being understood that the condition of the bridge was a subject of greater complaint at high than at low stages of water, the board awaited the intimation of Mr. J. W. Bissell, agent of the Saint Louis Chamber of Commerce, that the river was in a favorable condition for examination, upon the receipt of which information it proceeded to Davenport, Iowa, arriving there on the 22d of April last. At Davenport the Board found Mr. Bissell, with assistants, instruments, &c. It also met the president, superintendent, and other officers of the railroad companies interested in the bridge, from whom it received detailed drawings of the bridge in all its parts, with surveys of the river and other valuable information, saving much time in the examination.

The Board takes this occasion to express its thanks to all of the above-mentioned gentlemen for the courtesy extended to it during its visit.

As the Board was advised of the fact that the expenses were to be borne by the Saint Louis Chamber of Commerce, and found Mr. Bissell prepared with the necessary means, it proceeded at once to make the observations requisite to enable it correctly to report upon the various points submitted to it in its instructions.

From the drawings above alluded to, and from personal examination, the Board found that the railroad bridge is placed at the foot of the rapids, and is thrown from the island of Rock Island to the city of Davenport, Iowa; that it is supported by two stone abutments on the shores and six stone piers. The spans (five in number) are 250 feet broad, the draw-spans being at the water level (9½ feet stage) 117 and 112 feet, respectively, making the whole length of the bridge 1,535 feet.

The piers, except those of the draws, are 35 feet long and 7 feet broad at top, and 53 feet long and 11 feet broad at the bottom. The two small draw-piers are 38 feet long and 10 feet broad at top, and 54 feet long and 14 broad at the bottom. The turn-table pier, including the guard-pier and starling, is 355 feet long and 40½ feet broad at the top, and 386 feet long and 45 feet broad at the bottom.

This pier is composed of a stone center pier 35 feet in diameter at the top, the remainder being crib-work filled up with stone. The up-stream starlings of all the piers are isosceles, right-angled triangles. The center line of the roadway crosses the turn-table pier 210 feet from its head; this pier being 115 feet longer and 19 feet wider on top than the truss which forms the draw. The superstructure of wood, built upon Howe's patent, is 20 feet above ordinary high and 33 feet above ordinary low water.

The first points to which the Board directed its examinations were the velocities and directions of the currents. To determine these with accuracy, bases were measured above and below the bridge, and observers, with theodolites, were stationed at each extremity of these bases. Floats of different depths, ranging from 1 to 8 feet, were started in all parts of the stream, and simultaneous angles were taken to them at given intervals, by which means the exact path of the float and velocity were determined with accuracy. Additional observations were made with Masi's patent log, care being taken to compare a sufficient number of velocities obtained from these with those determined by the floats, to get the correction which these instruments require. The results of these observations are shown graphically on the map submitted with this report, and are also tabulated and annexed in the Appendix C.

By examining the map and table, it will be seen that the current in the main channel at a point 1,200 feet above the bridge, and beyond its influence, is 4.3 miles per hour; that under the bridge it varies from 4.5 to 6.4 miles per hour; and that at a point 1,700 feet below the bridge, where the river has resumed its regimen, the current is 3.75 miles per hour; and, finally, that at a point one mile below the bridge it is only 2.8 miles per hour.

It will be seen that above the bridge the direction of the current makes with the axis of the piers different angles, varying from 26° to 14° 30′; that, through the Illinois draw of the bridge, the angle with the axis of the pier is 5°, and that below the bridge the angle varies from 8° to 9° 30′.

After obtaining the directions and velocities of the currents the differences of the

level of the water in and about the Illinois draw were determined. These levels are shown in the annexed sketch (Appendix D). An inspection of these levels will show that the fall of the water from the head to the foot of the turn-table pier is 16 inches. Other differences of level are also given. The Board, with the data furnished by the company, viz, the cross-section of the river under the bridge, and the detailed dimensions of the piers, has computed the obstructions to the flow of the water due to the submerged part of the bridge. The obstruction due to each pier was computed as follows: The cross-section of the submerged part of the pier, perpendicular to its length, was computed from the data furnished by the railroad company. This area was multiplied by the cosine of the angle of inclination of the current to the axis of the pier. The product was the obstruction due to the width of the pier.

The area of the submerged side of the pier was multiplied by the sine of the angle of inclination of the current to the axis of the pier. The product was the obstruction due to the length of the pier. This product added to the first gave the total obstruction due to the pier. The starlings have been left out of consideration in the calculation, and only the lengths of the straight part of each pier has been taken. The results of these computations are attached to this report (Appendix E).

An inspection of this table shows that the total obstruction presented to the flow of the water is 4,881 square feet, and that the portion of this amount due to the inclination of the current is 3,216.2 square feet, or .66 of the whole; that is, were the same piers placed parallel to the current, the obstruction to the flow of the water would be about one-third of what it now is.

The Board also computed the height of backwater due to this obstruction, and the increase of velocity imparted to the current thereby. The data for this computation were the elements of the cross-section and piers as furnished by the railroad company and the assumed mean velocity at the site of the bridge, prior to its construction, 4 miles per hour. This last quantity was deduced in the absence of actual observation by finding it to be the mean velocity above the bridge and beyond its influence at a point where the area of the cross-section was the same as that of the site of the bridge. The computations and their results are given in the Appendix F.

The general level of the river is raised by the piers of the bridge .49 foot, or nearly 6 inches, and the increase of the mean velocity due to the contraction of the water-way is 2.27 feet per second, or 1.55 miles per hour, making the computed velocity under the bridge 5.55 miles per hour.

The Board finally examined the river below Rock Island, and carried a line of soundings across the river on the line of the ferry between the cities of Rock Island and Davenport. The maximum depth in the channel-way was found, near the Iowa shore, to be about 22 feet, and the velocity of the current 2.8 miles per hour. The bottom in the channel-way was rock, and in other parts coarse gravel and sand.

The Board has now presented all of the facts collected by it, and proceeds to report *seriatim* upon the points referred to in the letter of the Bureau of Topographical Engineers, dated March 1, 1859, a copy of which is hereto appended. (Appendix B.)

1. The Board is of the opinion that the railroad-bridge which crosses the Mississippi River between Rock Island, in the State of Illinois, and Davenport, in the State of Iowa, is not constructed according to correct principles, reference being had to the interests of navigation.

2. The piers of the said bridge are not of the best form, and that there was no practical difficulty in constructing them of the proper form. With the exception of the turn-table pier, the Board is of the opinion that the defective form of the piers is a matter of no material importance. The turn-table pier will be more particularly referred to in the answer to the next question.

3. The only pier larger than is necessary is the turn-table pier. This pier, in the opinion of the Board, should have been constructed no longer or broader than was absolutely necessary to sustain the truss when the draw is open, and protect it from injury by passing boats. It might have been constructed with a length of 295 feet, affording ample support and protection, and being actually 355 feet in length; the difference, 60 feet, is unnecessary, and, in the judgment of the Board, pernicious. The effect of making it longer than was absolutely required is to contract the water-way, increase the velocity, narrow the draw-passage, and present more surface for boats to strike against, thus increasing the difficulty of their passage through the draw. In a pier of this size, the form of the starling is of importance, and the upper faces of the pier should have been curved surfaces.

4. The piers are not placed parallel to the current, but at angles varying from 26° to 14° 30′. The effect of this obliquity is to treble the obstruction to the flow of the water, and consequently to affect the increase of velocity in the same ratio. Another consequence is that the passages of steamboats and rafts through the draw and between the piers are rendered much more difficult and hazardous. Furthermore, the draw on the Iowa side is rendered useless by the formation of an eddy therein.

5. The velocities of the different parts of the river in the vicinity of the bridge have already been stated, and will be found tabulated in Appendix C.

6. The eddy on the Iowa side of the turn-table pier, as nearly as could be estimated, is about 100 feet at the foot of the pier, and the turbulence or boiling of the water extends about 500 feet below. This eddy, however, is constantly varying in its position and dimensions. Its effect on the passages of boats ascending and descending is undoubtedly to render them more difficult, on account of the care required to avoid getting one part of the boat in it while another part is in the current of the draw. It has been previously stated that the effect of this eddy in the Iowa draw is to render it useless.

7. The surface of the water at the up-stream end of the turn-table pier is 16¼ inches above the surface of the water at the down-stream end. The extent of the backwater or *remous*, as nearly as could be estimated, is about 150 feet.

8. The bridge is badly located, and, in consequence of this bad location, is a greater obstruction to the passages of steamboats and rafts than would have been necessary had the location been good. Any site in the vicinity below Rock Island, out of the rapid current, would have been better. The Board, having this fact in view, examined the line of the ferry between Rock Island City and Davenport, and found that there would be no practical difficulty in the erection of a bridge at this site or near it, which bridge, if constructed on proper principles, would be no material obstruction to navigation.

9. The Board, under this head, deems it expedient to submit a statement of the number of steamboats and rafts which have passed the bridge, as well as the number of passengers and loaded cars that have crossed it since its opening. These statistics, obtained from the records and reports of the railroad company, are submitted to show the magnitude of the interests involved in the commerce that passes over and under the bridge (Appendix G). The Board passed the bridge in steamboats, ascending and descending, and also witnessed the passage of numerous boats and rafts.

The question of the practical difficulty of passing the bridge being dependent on the size and power of the boat, the draught of water, shape of hull and obedience to helm, shape of the upper works, and direction and force of the wind, together with the personal skill and judgment with which the boat is managed—conditions varying with each boat, and requiring special knowledge—the Board has not thought it incumbent upon it to enter into its discussion, particularly as it is well known that this matter is now before the courts, and that the testimony of experts is being taken.

The Board, too, has considered that the duty imposed upon it is one purely of engineering.

In this view of the case it has endeavored to collect all of the facts and data for the correct solution of the problem, with an earnest desire to bring into the discussion only material points, and in its deductions to do justice to all parties concerned.

In conclusion, the Board considers it proper to recapitulate some of the well-known principles of bridge-building, to show how far they have been conformed to or departed from in the Rock Island bridge. These principles are:

First. That at a given place, in locating a bridge over any stream, the site where the velocity of the current is a minimum should be selected.

Second. That in designing a bridge the piers should have a minimum cross-section consistent with the support of the superstructure, thus offering the least obstruction to the flow of the water, and increasing the velocity of the current as little as possible.

Third. The piers should always be placed parallel to the thread of the stream for the same reasons as those stated in the second principle, and because they thus render the passage of boats and rafts less difficult.

Fourth. In designing a bridge over a river having a large commerce in boats and rafts, the draws and spans should be of the greatest practicable width.

In applying these principles to the Rock Island bridge the Board is constrained, with extreme regret, to report that all have been violated; thus rendering the bridge not only an obstruction to the navigation of the river, but one materially greater than there was any occasion for.

The Board fully appreciates the value and importance of the railroad traffic, and is of opinion that a bridge is necessary, and should be constructed, not only at Rock Island, but at other points on the Mississippi River; but it is also of opinion that the interests involved in the free navigation of this noble stream demand that in locating and constructing these bridges, unusual study should be brought to bear to insure the presentation of the least possible obstruction to the navigation, and that all considerations of expediency and economy should be made to yield to the paramount interests of the commerce of the river.

Very respectfully, your obedient servants,

A. A. HUMPHREYS,
Captain Corps Topographical Engineers.
GEO. G. MEADE,
Captain Topographical Engineers.
WM. B. FRANKLIN,
Captain United States Topographical Engineers

Col. J. J. ABERT,
Corps Topographical Engineers, Washington, D. C.

There was no longer a doubt that this bridge was a most serious and dangerous obstruction to navigation, owing to its bad location and faulty construction.

A final hearing of the case of Ward *vs.* The Mississippi and Missouri Railroad Company was had before Judge Love, at the March term of 1860, at Keokuk, Iowa. The testimony of the members of the Board of United States Engineers was taken at this hearing. The court, on the 3d of April, ordered, adjudged, and decreed as follows:

That that portion of the railroad bridge across the Mississippi River at or near Davenport, within the State of Iowa, being a part of the commonly called Rock Island Bridge, and which is a part of the Mississippi and Missouri Railroad, is a common and public nuisance and a material obstruction to the navigation of the said river by steamboats and other craft; that so much thereof as is within the State of Iowa, to wit, all the piers between the long or turn-table pier and the Iowa side, was at the time of filing the said bill and has ever since been the property of the defendant, and in the possession and under control of the defendant. That the complainant was, at the time of filing his bill, and for a long time prior thereto had been a boat-owner and navigator of the Mississippi River by steam and a commander of steamboats in the trade from Saint Louis, Mo., to Saint Paul, Minn., and so continued to the time of this decree; that he was at the time of filing his bill the owner of the interest in the steamers *Connewoga*, *Pembina*, and *Canada*, set out in the amendment to his bill, and that they were of the value therein stated, and was the commander of the *Canada*, and continued such owner and commander to the time of this decree; that he was, at the time of filing his bill, engaged with said boats in the same trade, carrying freight and passengers, and so continued during the time aforesaid; that said boats were during all that time duly filled up, manned, equipped, inspected, licensed, and enrolled under the laws of the United States relating to vessels propelled in whole or in part by steam, and carrying freight and passengers, and to those relating to the coasting trade and fisheries, and were being used by the complainant in carrying on commerce in said trade under said laws as common carriers of passengers and merchandise; that as such owner, commander, navigator, and common carrier, the complainant, at the time of filing his bill, had, and continued to have, a special and peculiar interest in the navigation of said river between the points aforesaid, and in its commerce between the same, and at the place where said bridge is located; that said bridge is a material and serious damage, hinderance, and obstruction to him in his said business as a navigator and owner of steamboats engaged in said commerce, and that he suffered large and irreparable injury therefrom at the time he filed his bill, and continued so to suffer such injury, and for which there was and is no adequate remedy at law, and that he is entitled to have said bridge abated and removed and the river restored to its original condition.

And the court does further order, adjudge, and decree that the defendant abate and remove all of the said piers within the State of Iowa, together with the superstructure thereon, on or before the first day of October next; that said defendant commence said abatement and removal within thirty days from the entry of this decree, and proceed therewith as rapidly as it may reasonably be done; and that they remove the pier next to the long pier on or before the first day of July next, and the remainder of it by the first day of October next.

It is further ordered, adjudged, and decreed that in default of said abatement and removal as aforesaid, that an order issue to the marshal of the district requiring him to abate and remove the same as is hereinbefore provided, and that he summon to his aid all necessary and proper assistance therefor.

It is further ordered, adjudged, and decreed that the said removal be made at the costs of the defendant, and said defendant pay all costs which have now accrued, taxed at $, within ninety days from entry of this decree, and any and all further costs in executing this decree from time to time as they accrue, and within forty days from the time of their taxation, and in default of the payment of the costs aforesaid that execution issue therefor.

On the 4th day of April, the solicitor for the railroad company prayed an appeal to the Supreme Court of the United States from the decree of the district court, which appeal was allowed on the filing of a bond for the sum of $10,000.

The decision in this appeal by the Supreme Court was that the court in the district of Iowa had no jurisdiction to remove the part of the bridge which was within the State of Iowa. There were three dissenting judges, but neither they nor the majority touched the question as to

whether the bridge was or was not a material obstruction to navigation. This case, Ward *vs.* The Mississippi and Missouri Railroad Company, is reported in 2 Black's Supreme Court Reports, p. 485.

There was no longer a question that some further action on the part of Congress was necessary to give to the courts the requisite jurisdiction to try suits against the bridge company. The troubles preceding the war which broke out in 1861 probably absorbed too much of the attention of Congress to allow of any further consideration of the case at that time or at any time until the war was over. Then it was decided to establish an arsenal on Rock Island, and to have the railroad track removed to such part as would not interfere with the use of the island for the purposes of an arsenal, and to build a new bridge adapted to the uses of a highway as well as a railway. The first act for removing this bridge was approved June 28, 1866; it made the same requirements in the interests of navigation as the act authorizing the bridge at Quincy, Ill., passed at the same session. In 1872, the new bridge being finished, the first bridge was taken down.

This bridge is described in the report of the board of engineers inserted above. It is shown on the map of the new bridge (Diagram 20) accompanying this report, Chapter IV, with very numerous observations upon the currents as they were about the piers.

In the debates upon the bill for the removal of this bridge but little was said concerning the bad features of it, but they were frequently referred to in the debates upon the bill authorizing a bridge at Quincy, Ill., and in the debates upon the bill declaring the bridge at Clinton a post-route, abstracts of which debates are given further on.

The following is an abstract of the debates upon the act of 1866, which provided for the removal of this bridge:

In the Senate, on May 21, 1866 (Debates, page 2706), Mr. WILSON, chairman of Committee on Military Affairs, reported Senate bill, No. 330, to provide for occupying Rock Island as an arsenal. On May 22 (p. 2738) Mr. WILSON explained objects of the bill. It proposes to direct the Secretary of War to fix and establish the position of Chicago and Rock Island Railroad on the island of Rock Island so as to best accord with the purposes of the government in its occupancy of that island for military purposes.

The bill passed.

In the House of Representatives on May 23, 1866 (p. 2780), Senate bill No. 330, Rock Island arsenal, &c., received.

On May 26 (p. 2839), referred to Committee on Military Affairs.

On June 22 (p. 3351), Mr. SCHENCK, chairman of Committee on Military Affairs, reported Senate bill No. 330, with an amendment as a substitute. It extended the provisions in regard to the bridge, and made them more definite and positive.

The bill was explained and passed.

On June 22 (p. 3337), Senate bill No. 330, bridge at Rock Island, &c., returned from the House to the Senate.

On June 22 (p. 3349), Mr. WILSON said:

> The amendment is a substitute which I recommend.

This was agreed to.

In the House of Representatives, on June 23 (p. 3375), message received from the Senate that the substitute was adopted and passed.

Both the cases of the bridges at Wheeling and at Rock Island illustrate the great delays attending all attempts at redress in suits in equity, and the necessity for Congressional legislation to regulate the building of bridges so as not to unnecessarily obstruct navigation.

ABSTRACT OF DEBATES IN CONGRESS PRECEDING AND ATTENDING THE LEGALIZING OF BRIDGES ACROSS THE MISSISSIPPI RIVER.

In completing the history of the first Rock Island Bridge above, I have been carried beyond the time of the authorization and building of the important railway bridge across the Ohio River at Steubenville; but, as I shall have occasion to particularly refer to it further on, when speaking of my official duties connected with it, I have thought best to continue the account of the Mississippi River bridges. The following abstracts of the Congressional debates are not only interesting as a part of the history of the subject of bridging, but show the points raised and directions in which I was expected to pursue the investigations which Congress then authorized:

The subject was introduced in the House of Representatives on December 20, 1865 (Debates, p. 70), by Mr. HARDING, of Illinois, by a joint resolution to declare a certain bridge and ferry across the Mississippi River at Quincy, Ill., a post-route and national highway of commerce. It was referred to the Committee of Roads and Canals.

On February 19, 1866 (p. 919), Mr. WILSON, of Iowa, introduced into the House of Representatives a bill to authorize a bridge at Keokuk, Iowa, for a railroad and wagon-road, and declare it a military and post-road, which was referred to the Committee on Post-Offices and Post-Roads.

In the Senate, on February 23, 1866 (p. 979) Mr. HOWE, of Wisconsin, introduced Senate bill No. 163, authorizing Milwaukee and Prairie du Chien Railway to bridge the Mississippi River, which was referred to the Committee on Post-Offices and Post-Roads.

On March 7, 1866 (p. 1333), Mr. PAINE, of Wisconsin, offered in the House a bill to authorize a bridge at Prairie du Chien, Wis., and declare it a post-route, which was referred to the Committee on Post Offices and Post-Roads.

On March 8, 1866 (p. 1252), in the Senate, Mr. RAMSEY, chairman of the Committee on Post-Offices and Post-Roads, reported Senate bill No. 163 with amendments.

On March 27, Mr. TRUMBULL introduced Senate bill No. 236 to establish certain post-roads (a bridge and ferry across the Mississippi River at Quincy, Ill.), which was referred to the Committee on Post-Offices and Post-Roads.

On April 12 (p. 1906), Mr. NORTON introduced Senate bill No. 263, authorizing the Winona and Saint Peter's Railroad to construct a bridge as a post-route, which was referred to the Committee on Post-Offices and Post-Roads.

On April 16 (p. 1954), Mr. RAMSEY introduced a joint resolution to appoint a commission of Army engineers to examine and report upon construction of railroad bridges across the Mississippi River.

On April 19 (p. 2033), Mr. RAMSEY reported Senate bill No. 236, with amendments.

On April 25 (2163), Mr. RAMSEY, in explanation of Senate bill No. 236, said, it makes it lawful for any one having authority from the State of Illinois to build a bridge at Quincy, Ill., to be a pivot draw-bridge, the openings each side of this pivot to be not less than 150 feet, placed at an accessible and navigable point, and of the next adjoining spans not less than 250 feet; there must be a span over the main channel of the river not less than 300 feet in length; the bottom chord to be not less than 30 feet above low water, nor less than 10 feet above high water; to be recognized and known as a post-route. He amended (1st) to require

the authority of Missouri as well as Illinois, which was agreed to; (2d) to provide for litigation, by extending the jurisdiction of the United States district courts over the bridge in any State in which any portion of the bridge touches; this was agreed to; (3d) to strike out the provisions for length of span, and, instead, leave it optional to make it with a draw or with continuous spans. In the latter choice, elevation of bottom chord must not be less than 50 feet above extreme high water and the spans not less than 250 feet, with piers parallel with the current; if a draw-bridge with a pivot, the draw must be over the main channel at an accessible point, and with spans of not less than 175 feet in length on each side of the pivot pier, and the next adjoining spans not less than 250 feet; the bottom chords not to be less than 10 feet above high water nor less than 30 feet above low water; amendment agreed to.

Mr. HENDERSON, of Missouri, desires to amend by adding Hannibal, Mo., after Quincy, Ill.

Mr. RAMSEY objected, and suggested its withdrawal, and that it be offered as a separate bill.

Mr. HENDERSON pressed his motion and stated his reasons. He thought it an act of justice to Hannibal, which had every claim to the privilege that Quincy had. He lived within 30 miles of both places. He was opposed to all low draw-bridges, and would vote against the bill even if his own amendment was adopted. The bridges built under these provisions would surely be draw-bridges, not high continuous spans. He claimed that they should be high bridges, as provided in the bill for Saint Louis, with bottom chords 50 feet above extreme high water, but instead of spans 600 feet, he would accept 400 feet.

A Senator said, "It cannot be done."

Mr. HENDERSON said, "Mechanics say it can be done; they inform me that a span of 600 feet can be built."

Another Senator said, "Only by iron suspension."

Mr. HENDERSON answered, "I care not how it may be done. We want high and wide spans. In the course of a few years transportation by barges alongside of steamboats has come into practice, requiring much more space than formerly. Rafts are sometimes 300, 400, and 500 feet in length. It may be said that rafts are never as wide as 150 feet; that I do not know, but some are very wide, and repeated difficulty has been experienced in getting them through the Rock Island Bridge. A raft may enter the opening properly, but before the entire raft gets through it may strike the piers."

Mr. GRIMES said, "The bridge at Rock Island is right at the foot of the rapids, where the current is very strong; but no such condition can exist at Quincy."

Mr. TRUMBULL said, "The span there is only 112 feet."

Mr. RAMSEY said, "The whole difficulty at Rock Island is the obliquity of the piers to the current."

Mr. HENDERSON said, "That is the very difficulty that I am suggesting."

Mr. RAMSEY said, "That is well guarded against in this bill. They are here required to be in the line of the current."

Mr. HENDERSON said, "But it may be that they are in the line of the current in low water, and yet will not be in the line of the current at high water. The current of the Mississippi is not always in the same line; the current changes even in high and in low water."

On April 26 (p. 2192), Mr. NORTON moved that Senate bill No. 263 be printed. Ordered.

On April 30 (p. 2266), Mr. HENDERSON withdrew his amendment for the present.

Mr. GRIMES offered an amendment to authorize bridge at Burlington, Iowa.

Mr. RAMSEY spoke at length on the general subject. He described the three bridges built at Saint Paul, Clinton, and Rock Island: the first high and no obstruction, the others alleged to be very obstructive. He quoted from the report of board of United States Engineers, condemnatory of the Rock Island bridge, and explained the action of his committee. The provision for continuous spans with bottom chord 50 feet above high water, he said, experienced river men told the committee was all that is desired.

Where the chimneys are taller than that, the arrangement is to lower them upon the telescopic plan, which has been introduced there.

With regard to the spans other, than the pivot span, we have the information of competent engineers that an excess of 300 feet is not advissable. General McCallum, civil engineer, who had charge of railroad and bridge structures during the war, says:

The longest draw-bridge ever constructed in this country is of two openings of 150 feet each. Although I do not consider even a greater width impracticable, I nevertheless would consider it unnecessary and impolitic. Any bridge located at right angles with the stream, with current of not more than 4 miles an hour, all purposes of navigation should be fully met by 150 feet openings.

Mr. HOWE said, "I understand the bill provides for these openings to be 175 feet."

Mr. RAMSEY. "No; the pivot-pier and the one-half of the rest-pier at each end on which it rests detract from their width. The length of the whole span is 350 feet and leaves a clear draw of 150 feet. That much can be done, and I think it ought to be conceded. I think in this bill we have guarded all these various interests on the river. We have insured a passage-way sufficiently large, the piers to be in line with the current; to be 50 feet above high water, if with continuous spans." He said, "I would oppose bridging in the interest of my State and of navigation if we could avoid having bridges, knowing that the river trade of 1865 amounted to twice as much as our foreign commerce; but, from the immense capital invested in the railroads that approach the river, they will cross it. It cannot be expected that they can be successfully resisted forever. The fact is, that almost in spite of law they are building bridges. It is, then, important at this time, before these structures are up, when it will be impossible to remove them—the interest retaining them being so large—that Congress should step in and regulate the construction so as to be as little injurious to navigation as possible."

Mr. HOWE asked what evidence there is that a draw of the length prescribed is manageable.

Mr. RAMSEY said, "There is an iron swing-bridge at Brest, France, spanning a water passage of 347 feet in the clear, which cost $406,000. It is a government work. It is desirable we should strike a medium in the erection of these swing-bridges across the Mississippi, so as to neither injure the river nor the bridge interest. If we make them too large, they will often be out of order and immovable, and the boats cannot pass. If they are made of smallest size, as requested by some, the channel-way will not be large enough for business. They should be easily workable, and at the same time as large as can be allowed. This is the proper medium."

Mr. GRIMES stated he would support the bill, and said that the draw at Rock Island was only 112 feet."

Mr. RAMSEY said, "One is 112 feet, the other 117 feet."

Mr. GRIMES said, "This bill requires the draw to be 175 feet."

Mr. RAMSEY said, "Not 175 feet, but 150 feet; probably a few feet more."

Mr. TRUMBULL said, "That had better be more definite, so as to make its meaning clear."

Mr. GRIMES said the bridge company could always locate the draw so as to have the current at all stages directly through it. He knew the currents changed, but experience had shown that works could be built to preserve them in a desired course.

Mr. RAMSEY said, "I have the opinion of Captain Blakely, who has a long experience in navigating the Mississippi River, to the effect that the draw-openings should not be less than 150 feet in the clear, and, if practicable, 175 feet in the clear. Capt. W. F. Davidson, a long and successful navigator, says he thinks the bill should be amended so as 'to force the company to build a draw,' considering that less obstruction than the bridge with continuous spans."*

The committee did not feel at liberty to report against allowing these bridges, and, in many respects, thought it desirable to seize this opportunity of regulating them. Mr. RAMSEY said he would, however, at the same time, desire that Congress should authorize the President or Secretary of War to send a commission to survey the whole river, and decide, at least as to the future, what should be the character of the bridges there. The probability is that before the close of the next session of Congress you will be compelled to authorize a dozen of these bridges. The thing will get to be serious when they come to be so numerous as that. I think we have guarded this bill as well with the light before us as it was possible to do, and yet I should like, when this expensive building of bridges on the Mississippi River is entered upon, to have the opinion of a Board of scientific Engineers; and, with that view, some days since I introduced a joint resolution, which was referred to the Committee on Commerce, but they have not seen fit to return it with a report. I feel reluctant to vote for any other bridge than the one reported by the Post-Office Committee on this bill, simply because it is but one, though I have no particular objection to any other, except as to the number; but I hope when this bill passes we shall authorize a commission to be sent to survey the river and determine and settle the essential points to be guarded in the construction of these bridges, how, when at the same time the railroads may be accommodated, the navigation shall be preserved. My resolution was in the following language:

"That the Secretary of War be directed to appoint a commission, to consist of three officers of the Corps of Engineers of the Army, to examine and report at the present session of Congress, if practicable, and, if not, before the next session of Congress, upon the subject of the construction of railroad bridges across the Mississippi River, at such localities and upon such plans of construction as will offer the least impediment to the navigation of the river; and that $10,000, or as much thereof as may be necessary, be hereby appropriated.

"I should much prefer before very many bridges are authorized that this commission should be sent out to view the river, and furnish us the best information on the subject."

Mr. HENDERSON offered an amendment making an additional section to the bill, and authorizing a bridge at Hannibal, Mo. It was agreed to.

Mr. HENDERSON next proposed to amend the second section by striking out that part which left the bridge-tender to decide whether the boat could go under or not after receiving the signal for opening the

* Since the building of the draw-bridges Captain Davidson has retracted this opinion.—G. K. W.

draw. He thought there might be a troublesome question raised here between the bridge-men and the boatmen. This amendment was rejected.

Mr. HENDERSON moved to amend by striking out the fourth section, declaring the ferry at Quincy a post-route.

Mr. GRIMES sustained the amendment.

Mr. TRUMBULL opposed it, but said he had no interest in it further than to authorize these great lines of travel to accommodate themselves to each other. He thought the time had come when we have got to have bridges.

The amendment was agreed to.

Mr. HENDERSON wished to further amend by compelling the bridge to be of continuous spans. He said that all the interests he represented wanted high, continuous spans. He said when the law authorizing the bridge at Steubenville was passed, Senator Collamer, who reported it, requiring spans of 300 feet, said he did not believe it possible, yet it was built, the bridge costing $900,000. The Senate being in Committee of the Whole, and this an amendment to an amendment already agreed upon, was decided to be out of order; the bill was then reported to the Senate.

Mr. TRUMBULL moved to make the bill so read that the draw-openings should be 150 feet in the clear, which he understood to be the intention.

Mr. RAMSEY said that, as worded, the widths of the pivot and adjoining piers might be such as to leave a little more than 150 feet in the clear, and inasmuch as he would like to have 200 feet in the clear he wished to hold on to all the bill allowed as reported from the committee.

Mr. HENDERSON opposed Mr. Trumbull's motion. The bill was clearly drawn with the idea that the openings should be 175 feet in the clear.

Mr. RAMSEY said they were not expected to be that in the clear.

Mr. HENDERSON urged to have wider draws. He said, "They have wider ones in France; why cannot we have them here? Is it possible to build a bridge with a draw 175 feet? If so, there is no stream on God's earth that requires this width of draw more than the Mississippi. I warn the gentlemen, who are just as much interested in this subject as I am, that they are doing a thing this morning they will regret in the future. They should remember that they are interfering with that navigation which is much better for the people than any transportation they can get by rail."

Mr. GRIMES said that the river takes the transportation in the wrong direction. "We are not only anxious sometimes to go to Saint Louis, but for facilities for reaching the eastern cities. We want, if possible, to be able to do so in the winter, when the ice is running, when it is impossible to cross sometimes for weeks in succession without great risk of life; and we want the opportunity, when we choose, to send our freight and live-stock to the only market we have, without breaking bulk at the Mississippi River. This bridge is opposed, because it does not give sufficient opportunity for boats to pass. Did not the three Army engineers state that the objections to the Rock Island bridge were solely because the piers were not parallel with the stream? Is not this bill prepared to meet that objection? I, who live on the Mississippi, and represent several tolerably important towns, am deeply interested in the navigation of the river, and I would not do a single thing here or elsewhere that could by any possibility obstruct the free navigation of the stream; but we want at the same time, if it can be done, and we are satisfied that it can be done, opportunities to get eastward as well as southward and northward."

Mr. HENDERSON said he considered the bill to mean clear openings of 175 feet, else why did the chairman of the committee read a letter from a steamboat captain saying such a width was required?

Mr. TRUMBULL said the chairman had twice stated he did mean that, and it is best to have the wording so that there shall be no doubt about the meaning. I have consulted the Senator from Minnesota (Mr. Ramsey), and he is willing to make it specific, by saying the openings shall not be less than 155 feet.

Mr. RAMSEY said, "I agree to that."

Mr. HENDERSON said, "I will compromise with the Senator from Illinois, if he will put it at 160 feet."

Mr. TRUMBULL said, "Well, I will agree to that."

Mr. HENDERSON said, "Very well."

The amendment was agreed to.

Mr. HENDERSON proposed to amend by inserting the requirement that, if with continuous spans, the main span should be over the main channel and not less than 300 feet wide.

Mr. RAMSEY said, "I do not insist that the spans shall be only 250 feet. I have the opinion of an engineer attached to the War Department. He says:

> In regard to the question of economy and practicability of truss-bridges for railroads, I have the honor to state that, in my judgment, spans of 250 feet in the clear are as great as should be adopted for crossing navigable rivers.

"These are the extent of the spans we are familiar with. The great bridge constructing across the Susquehanna River has spans of 250 feet. It is desirable to have 300 feet, if the Senate think they can be constructed of that width."

Mr. HENDERSON said, "Every bridge on the Ohio is built with 300 feet spans. It is a general law (pp. 289–290 of the Senate acts of 1861–'62). Several bridges have been built not under the law, and they have led to continual controversies in the courts."

Mr. RAMSEY said that "in a narrow stream a high bridge is easier thrown, but the Mississippi is wider than the Ohio."

Mr. HENDERSON said, "But that has nothing to do with the span."

Mr. RAMSEY said he had no objection to the amendment.

Mr. HENDERSON said, "I wish also to provide that, if a bridge with continuous spans, the span next the main span shall not be less than 220 feet, and no space over the part where water flows at low water shall be less than 175 feet."

Mr. RAMSEY said, "But you are shortening the length of spans from 250 feet to 220 feet."

Mr. HENDERSON said, "There certainly can be no objection to that."

Mr. RAMSEY said, "I do not object to enlarging the main span to 300 feet, but I do to reducing the other spans from 250 feet to 220 feet."

Mr. HENDERSON asked if there is any objection to the 300 feet span.

Mr. KIRKWOOD said, "That is assented to, I understand."

Mr. HENDERSON said, "I suppose that is not a matter of very great consequence, because all these bridges will now be built with a pivot-pier."

He then proposed an amendment to include all the provisions he had presented.

The amendment was rejected—yeas, 7; nays, 21; absent, 21. There was apparently a misunderstanding, for right after this vote the amendment to have the main span 300 feet and over the main channel was adopted.

The Senate then concurred in the amendment as amended, and also adopted the additional section providing for a bridge at Hannibal.

Senate bill No. 236 was then passed.

On April 30 (p. 2299), Senate bill No. 236, to authorize certain bridges and to establish post-routes, was received in the House.

On May 1 (p. 2303), Mr. RAMSEY reported, in the Senate, Senate bill No. 263, with amendments.

On May 2, in the House, Mr. HARDING, of Illinois, moved that Senate bill No. 236 be printed; it was ordered. On May 3, Senate bill No. 236 was amended so as to authorize any railroad to build bridges on same terms; also specifying the bridge at Keokuk. The matter was debated, and the bill, as amended, referred to the Committee on Post-Office and Post-Roads.

On May 14 (p. 2562), Senate bill No. 263 was taken up in the Senate, and Mr. RAMSEY, chairman, said it had been considered by the Committee on Post-Offices and Post-Roads, who had the other bills in charge, and, as amended, it is similar to the one we passed a few days since. The amendments were agreed to.

On May 18 (p. 2665), Mr. HOWE said, "I desire to call attention to the amendment of the first section. Is not that a new principle? It is as follows:

> And in case of any litigation arising from any obstruction or alleged obstruction to the free navigation of said river, the cause may be tried before the district court of the United States of any State to which any portion of said obstruction or bridge touches.

Mr. RAMSEY (p. 2665) said, "It is embraced in all the other bills that have been reported here by the Post-Office Committee. It is to avoid a difficulty that occurred in the litigation in regard to the Rock Island bridge. I believe the proceedings were first had in the district court of Iowa; and I think it was then held they had jurisdiction only to the thread of the stream, and hence had not jurisdiction of the whole matter of the bridge. This is to give that jurisdiction to the courts."

Mr. HOWE said, "I have no objection to it."

Mr. RAMSEY said, "The amendment was suggested by those who have in charge the interests of navigation at Saint Louis."

Mr. HOWE proposed to amend the bill so as to allow the bridge to be built either at La Crosse or Winona, as the legislatures of the two States should elect.

Mr. NORTON opposed this because there was no railroad or authority to build one from Winona to La Crosse, and that the Wisconsin legislature would give it to La Crosse and the Minnesota legislature to Winona, and there would be no bridge at either place.

The debate continued on this amendment until the consideration of the bill was postponed.

On May 22 (p. 2760) Mr. HOWE'S amendment was further discussed and rejected.

Mr. HENDERSON offered an amendment to strike out the provision for a draw-bridge, and require continuous spans. He said: "High bridges of 400 feet spans of truss, are practicable. It was strenuously urged the other day, when a similar proposition was before the Senate, that one bank of the Mississippi is always low, and that, therefore, it will be impossible to build these high bridges. It seems to me better to intrust the matter to a board of scientific men—a board of engineers. The Senator from Minnesota (Mr. Ramsey) has proposed a resolution that I think this body ought to adopt before going into this business of bridging with low draw-bridges the Mississippi River. He proposes to have a scientific board established to go out and examine the Mississippi River

and see at what points it may be safely bridged, and report the character of the bridges that, under the circumstances, ought to be constructed. Let them go out and report to this body at the next session whether this thing is practicable or not; they can report by next December. Draw-bridges are an immense obstruction. I have been told by steamboatmen that an opening of only 160 feet will materially and permanently injure commerce. The Chamber of Commerce of Saint Louis have sent here a large delegation to protest in the name of the people of the West."

Mr. COWAN said, "I will vote for the amendment with pleasure. I have had considerable experience in the navigation of Western rivers, and I have a very clear and distinct opinion of my own that nothing could be more mischievous to the interest of the carrying trade of the country than the construction of such low draw-bridges. I have no hesitation in saying that it would be better for the United States to-day to appropriate $1,000,000 for the construction of a high bridge across the Mississippi River 90 feet or 100 feet above low-water mark, with a span of 600 or 700 feet, than build a draw-bridge upon a stream of that character. I have no doubt that Western men will regret their action in a very short time if they allow these great streams to be obstructed by erections of this kind."

The consideration of the bill was postponed.

On May 29 (p. 2866) Mr. HENDERSON said: "I want a test vote on this amendment; I want the commission sent out to see if such low bridges are a necessity, and that high bridges cannot be built; if they report that these high bridges cannot be built, I shall be willing to let the low ones be built. A proposition is now pending in the Senate, authorized by the Committee on Commerce to be attached to one of the appropriation bills, to appoint a Board of Engineers to go and examine the river and report as to the proper kind of bridges to be constructed."

Mr. GRIMES favored low bridges; the towns were mostly low down on the river banks; high bridges would not suit them; bridges would never be built except at railroad termini; ultimately they might average one for every 50 miles; the detention would not exceed 15 minutes in passing each. He knew the Burlington and Quincy bridges, if authorized, would be begun this summer, and time would be lost waiting for report of commission. Bridges of 400 feet span would embarrass the companies; they would be forever unsafe. They never should exceed 200 feet, and, in case of a pivot-draw, 300 feet from end to end.

Mr. POMEROY said: "The river is an obstruction to the railroad. The time is coming, and I think has already come, when the commerce of the rivers must give way to some extent and be discommoded by the commerce of railroads. Let the companies themselves judge of the character of the structure. Let them be allowed to build it where they have to cross the stream, and only require them not to obstruct the navigation of the river more than such structures necessarily do. That is the language of the law in regard to bridging the Missouri River."

Mr. GUTHRIE said he was decidedly in favor of high continuous spans; Congress had compelled the Louisville bridge to be 90 feet high above low water. "At the falls the highest rise is 44 feet; it has only reached this three times in the memory of man—1792, 1831, 1847. If the law had allowed us to build 70 feet above low-water, we would have been at work now. We have a draw-bridge at Nashville and have had a multitude of suits growing out of it, and are having them every year. I am satisfied that a skillful engineer who takes the whole subject into consideration, not only cost now, but trouble, vexation, and cost in the future, will decide in favor of continuous span bridges."

The further consideration was postponed.

On the 14th of June, in the House (p. 3166), Mr. WINDOM introduced a bill for a bridge at Winona, and establish it a post-route, which was referred to the Committee on Post-Offices and Post-Roads.

On July 12th (p. 3769), Mr. ALLEY, chairman of the Committee on Post-Offices and Post-Roads in the House, reported back Senate bill No. 236, with amendments. As referred, it provided for bridges at Quincy, at Burlington, and at Hannibal.

The bill was amended to provide for a similar bridge at Prairie-du-Chien.

Mr. ALLISON asked, "Why not pass a general law so as to authorize every railroad to bridge that wishes to cross the Mississippi River?"

Mr. ALLEY said the committee was unanimous against the passage of such a law.

Mr. HOGAN asked "If we had not passed a law directing the Secretary of War to make a survey of the Mississippi River to see where bridges can be built?"

Mr. ALLEY said, "I believe it is true, but I see nothing in this bill incompatible with that action, if this House sees fit to pass it." Amendment agreed to.

The next amendment was to expressly reserve "the right to alter or amend, so as to prevent or remove all material obstructions to navigation of said river by the construction of the bridges."

Mr. WILSON moved to amend so as to provide for a bridge at Keokuk. This amendment was agreed to.

Mr. WINDOM moved to amend by adding a section to provide for a bridge at Winona, with the same provisions as provided in Senate bill No. 263.

This amendment was agreed to after division—yeas, 80; nays, 34; absent, 68.

On the 14th July (p. 3811) this bill was further amended so as to include the provisions for bridges at Saint Louis, at Dubuque, Iowa, and for a bridge over the Missouri River at Kansas City, Mo. An amendment declaring the Clinton bridge a post-route was debated and rejected. The debate upon this amendment is given in the report upon Clinton bridge.

On July 16th (p. 3825) announcement was received in the Senate that the House had passed Senate bill No. 236.

On July 17th (p. 3854), in the Senate, Mr. RAMSEY reported Senate bill No. 236, and recommended concurrence in the House amendments.

On July 18 (p. 3898) the bill was taken up in the Senate. The first amendment by the House was for a bridge at Saint Louis, not to be a suspension or draw-bridge, the bottom chord to be 50 feet above the city directrix at the main span; to have one span at least 500 feet in the clear or two spans of 350 feet in the clear each. If the latter is built, the span over the main channel shall be 50 feet above the city directrix. This amendment was agreed to.

The next amendment, providing for a bridge at Keokuk, Iowa, was agreed to.

Mr. BROWN offered an amendment to construct a submerged tubular bridge at Saint Louis, but afterward withdrew it.

The bill then passed; but on motion to reconsider by Mr. HENDERSON, he offered an amendment as follows:

Provided, That if the board of engineers authorized under the laws of the United States at the present session of Congress to examine the Mississippi River and make report on the subject of bridge construction thereon, shall find and so report that elevated bridges of continuous spans can be constructed and operated without greater expense to the company building them than draw-bridges, and with less obstruction *to navigation*, then no draw-bridge shall be commenced or constructed under this act.

This Mr. HENDERSON advocated at length, and claimed that the authorizing of this board of engineers in the river and harbor bill meant that no bridge should be built till this engineer report was received. The Rock Island bridge is a nuisance which will, in the course of a few years, be declared such and taken down.

Mr. YATES replied, taking nearly the same ground as Senator Grimes, already quoted.

The amendment was rejected—yeas, 14; nays, 19; absent, 16.

Mr. HENDERSON offered an amendment that no draw-bridge should be erected prior to March 1, 1867. He again urged the importance of the engineer report before acting:

If the Southern States are represented again in the Congress of the United States, if these bridges are put across the river they will have to come down. Mark what I tell you. I predict to-day that these bridges will not be permitted to stand if Congress hereafter can vote them down, because they will prove an obstruction to the river. I am satisfied of that.

Mr. GRIMES argued that the low bottom-lands of the Mississippi would not allow of high bridges, without embankments, that would bring the towns where the railroads crossed; high bridges were to him utterly impracticable.

Mr. COWAN asked, "Why put the bridge at the town?"

Mr. GRIMES explained the character of the Mississippi River.

Mr. HENDERSON replied to Mr. Grimes's assertion as to impracticability of high bridges.

Mr. BROWN sustained his colleague (Mr. Henderson). He was not opposed to railroads. There was a universal protest from the navigation interests against draw-bridges. Give us the bridge of a height of 50 feet above high water, and make it a permanent structure, and we will forego our objection; we will take down our chimneys; we will change the construction of our steamers; we will dispense to a great extent with the height of our pilot-houses, and will adapt our system of navigation, as far as practicable, to facilitating the transit across the river.

Mr. JOHNSON advocated the amendment. He was counsel in the Wheeling Bridge case for the bridge. It was erected by the authority of Virginia alone. The court recognized the right of the bridge, provided a draw was made so that boats could go through when they could not go under; but if a draw or some other such provision could not be made it must be abated by raising it to 90 feet above high water. Congress passed a law, however, declaring the bridge a legal structure as it stood, and a majority of the Supreme Court held that that was within the power of Congress. Congress has a right to prescribe what draws bridges shall have, or whether or not to have any, and also the height of chimneys. We shall regulate these matters by law, but should wait for the report of the engineers before doing so.

The amendment was rejected—yeas, 11; nays, 25; absent, 13.

Mr. HENDERSON proposed to amend, so that there should be no bridge other than a submerged tubular one built until after the report of the engineers.

The amendment was rejected.

The House amendments were then concurred in.

The House concurred in the Senate amendments, and the President approved the bill July 25, 1866.

(For further information concerning the views of members of Congress on this question see reports on Clinton and Saint Louis bridges.)

The building of the Quincy bridge was set on foot as soon as the act

was approved, it already having been authorized by the States of Illinois and Missouri.

The provision of the river and harbor bill in regard to surveying the river did not specify a "board of engineers," and under it but one engineer was assigned to the charge of the work.

ABSTRACT OF PROCEEDINGS IN CONGRESS RELATING TO THE BRIDGE ACROSS THE MISSISSIPPI, AT CLINTON, IOWA.

In December, 1865 (debates, page 135), Mr. PRICE, of Iowa, introduced a joint resolution in the House of Representatives, declaring this bridge a post-route and highway, which was referred to the Committee on Post-Offices and Post-Roads.

On July 12, 1866 (debates, page 3769), Mr. ALLEY, of Massachusetts, chairman of House Committee on Post-Offices and Post-Roads, reported Senate bill 236 (authorizing bridge at Quincy, Ill., &c., which had been referred to this committee), with amendments, one of which was to make the bridge at Clinton a post-road, provided it does not materially obstruct navigation. A very instructive discussion on this amendment took place in the House of Representatives on July 14, 1866.—(Pp. 3811–3818 of the debates.)

Mr. WASHBURNE, of Illinois, offered an additional provision, that this section should in no way interfere with lawsuits now pending, and not take effect until the said bridge shall be made to conform in width of draw and all other respects with what is required to be done with reference to all other bridges referred to in this bill.

Mr. ALLEY would not accept this. He said his committee had given both sides a full hearing, and he had been directed, with one dissenting vote, to report a separate bill, but not being able to do so he put it as an amendment.

Mr. WASHBURNE opposed the bridge, as being built in defiance of law.

Mr. HOGAN opposed the Clinton bridge and all other bridges not giving at all times a clear height of 50 feet.

Mr. ALLEY said Clinton bridge had been in operation eighteen months.

Mr. WASHBURNE said the Rock Island bridge had been a damage to commerce already of $5,000,000, of which $2,000,000 was wrecks and damages. There were sixty-four steamboats lost, wrecked, or damaged, but because there was a question of jurisdiction arising, as well as other questions, the people who have suffered this great wrong are without a remedy. He said, "I have all the testimony here. The draw-openings at Clinton are 40 feet less than the width which the gentleman from Massachusetts has said is necessary for these other bridges. Why such discrimination in favor of this bridge? I have here the testimony of some 50 or 60 pilots and river-men on the Mississippi River. The men interested in navigation say said bridge is a dangerous nuisance, materially obstructing the navigation of the Mississippi River; that we respectfully pray and hope that Congress will in no manner interfere with the course of justice by legalizing this bridge. We have here the affidavit of some 15 or 20 more pilots:"

The undersigned pilots, captains, and experts in the navigation of the Upper Mississippi River, and owners of boats engaged in the navigation of the Upper Mississippi River, being duly sworn, state on oath that they believe the bridge constructed across the Mississippi River at Clinton, Iowa, as at present constructed, is a very material obstruction to the navigation of the Mississippi River; that they each and all have had experience and knowledge; that the same causes great risk to life and property in passing through the same, and causes great delay and loss to owners by detention.

on account of winds and darkness at times, when but for the bridge that portion of the river could be run with perfect ease and safety; that the said bridge is located where there is a curve in the river, and the piers are set at an angle of from 10° to 15° to the current, causing difficulties in the approach to the draw and danger of collision; that the draw is only 120 feet in width, and the difficulty is greatly increased when the boats have barges in tow; that the average width of a large boat, including guards, is 60 feet, and the additional width of two barges would be about 50 feet more, so that only 10 feet margin or 5 feet on each side is allowed; that where there is a current this margin is entirely too small for safe navigation even in calm weather, and that when there is any wind, or it is dark, the danger is greatly increased.

Mr. WASHBURNE continued:

"How was it in regard to the Rock Island bridge? Although we had no remedy, for want of jurisdiction, still it was such a nuisance that its friends finally gave it up. This House has passed an act at this session so that this bridge may be removed. But does this House know another thing? After the Senate had discussed for days this question of bridges, and passed the bill before the House, what did the Senate do? In the river and harbor bill they placed the following, which we adopted, and it is since become the law of the land."

This is the part of section 4 of the river and harbor act under which the examinations were begun, now being finally reported upon. At the end of the debate a vote was taken, and the amendment to constitute the Clinton bridge a post-route was lost—yeas, 54; nays, 66; not voting, 62.

On July 10, 1867 (see pages 391–398, debates), Mr. ALLEY, chairman of Committee on Post-Offices and Post-Roads, reported the bill (H. R. 965) declaring Clinton bridge a post-route.

Mr. WASHBURNE, of Illinois, opposed it, and claimed that its rejection last session should be final.

Mr. DAVIS said that no suit for damages had been brought against the company. There was a suit by way of indictment against it, in regard to which it asked the protection of Congress.

Mr. ALLEY said, "We want to connect with the commerce of the States, and if every time we propose to bridge the Mississippi River we are told that the commerce does not rightfully belong to the East, that it must pass through the Mississippi River, and that you must not dam up that stream, it would have been a great deal better for the country if there had never been a Mississippi River. The committee made very patient investigation, heard both sides, and disinterested parties, too, and were unanimously of the opinion that if any bridge is proper this one is." He said he thought that 120 feet draw-opening was enough for this locality, and as good as 160 feet in some other places.

Mr. WASHBURNE, of Illinois, said there is a suit now pending about this bridge in the United States district court of Iowa.

Mr. ALLEY said there was no testimony to that effect. Before the committee it was denied.

Mr. HOGAN said the difficulty has been to find out the parties to be sued.

Mr. WASHBURNE said there were numerous cases of damage from this bridge.

Mr. FARQUHAR claimed that this bridge should be treated as the Wheeling bridge was—made a post-route.

Mr. ALLISON sought to have action deferred until General Warren's report could be made, as he had examined the bridge.

Mr. WASHBURNE said they dare not trust that. The bill was passed—yeas, 101; nays, 43; not voting, 47.

On January 11, 1867, H. R. bill 965 was received in the Senate and referred to the Senate Committee on Post-Offices and Post-Roads. At

the request of the chairman, Hon. Alexander Ramsey, of Minnesota, I was ordered to appear before this committee. I laid before them a map of the river and sections at the bridge together, showing the location of the bridge, with arrangements of spans and direction and velocity of the currents in the Iowa or main channel where the draw is located. At the same time everything ascertained by the survey was fully stated and explained in answer to questions of the members of the committee.

By request of the chairman I put the general facts and views in writing, as follows:

WASHINGTON, *February* 5, 1867.

SIR: In compliance with your request to furnish you the substance of my remarks made to-day, I have hastily put together the following in relation to the Clinton bridge across the Mississippi River.

The map I left with you shows the relation of the structure to the two parts into which the river is divided by Little Rock Island and the sand-bars across which the bridge is located and a considerable portion of the river above and below the bridge. My examinations were made nearly at low-water.

The channel-way in which the pivot-pier and turning-bridge are placed is not less than 40 feet deep, and the current does not exceed two miles an hour. The clear spans each side of the pivot-pier are on the Iowa side 128 feet and 119 feet on the other.

Where the piers are situated the thread of the current is parallel with their lengths, but the current is at the time flowing on a curve sensibly parallel to the adjacent bank, and a steamboat is not able to head directly in the direction of the opening between the piers until she is quite close to them. The effect of this curve is further rendered objectionable by reason of an eddy formed below the point above the bridge, which eddy has an effect to vary the intensity and direction of the current near its outer margin so as to disconcert the plans of a pilot (in making his allowance for the swinging of his boat by the curved direction of the current) if he ventures too near the eddy. On this account the opening of the bridge on the Iowa side of the pivot-pier is seldom used. If we prolong the lines drawn through the middle of the draw-spans and perpendicular to the bridge till they reach the shore above the bridge, we find the distance of the one nearest the Iowa shore from the end of the pivot-pier to the shore to be about 500 feet, the other one to be about 1,000 feet. Steamboats at greater distances than these distances, less the length of the boat, could never be squarely opposite the openings left for them. These relations would produce very great difficulties to navigation if it were not for the low velocity of the current.

The effect of a side wind, is to require the pilot to place his boat's bow somewhat heading toward the wind, so as to make headway in opposite direction equivalent to the drift of his boat by the wind. She thus has to pass the piers somewhat obliquely and requires more space than in a calm. I am not able to state the effect of this in precise numbers for different cases, but it will evidently increase with the strength of the wind and length of the boat and diminish in proportion to her speed.

When the pilot approaches the bridge in dark nights, he should not be looking into a bend as he has to do at the Clinton Bridge, but should have a straight reach before him, so that the bridge and the opening may be seen against the sky or its reflection on the water, and not confounded with objects on the bank beyond or their reflection from the water.

I am not prepared to state fully the extent of the obstruction which the bridge is or may become to navigation. To make it conform as far as practicable to the law of Congress authorizing bridges at Quincy, Keokuk, &c., would require almost the entire rebuilding of it; and in view of the necessities of communication east and west, it would not seem proper to compel this change to be made before time can be had for a fuller investigation of the subject, and a proper bridge built to take its place if its removal be ultimately decreed. But in view, further, of the great importance of the river navigation to the whole country in the future, I think nothing should be done in the way of legislation which will prevent it being removed i necessary hereafter, or which will furnish an excuse to other companies to build bridges across the river which fail in the least to fulfill every practical requirement of the navigation.

I am asked the question, "Do you think it practicable to build a draw-bridge which shall be no serious obstruction to navigation?" and this I answer in the affirmative,* for I consider it will be no serious obstruction if it allows boats to pass without danger at all times of night and day and all kinds of weather in which they are able to navigate the average of the bad places of the river. The temporary inconveniences of having to wait the passage of a train is quite inconsiderable; but if compelled to lie by,

* I do not think now that a draw-bridge can be built that will not seriously obstruct navigation.—G. K. W.

so as to lose many hours that might have been used in progressing on their way, then I should consider it a material obstruction, that the necessities of the case do not require and should be abated.

The following things are required in a good location for a draw-bridge on the pivot plan:

1st. The open spans of the draw should be in the channel-way at a point where it is permanent at all times and stages of the water, and both openings should be available.

In the Clinton bridge but one draw-span is useful.

2d. The current should not only be in the direction of the draw-piers where they are placed, but should have this same direction from 1,000 feet above the bridge to 300 feet below at least.

This requirement is not met by the Clinton bridge.

3d. Where the steamboat pilot, when approaching the bridge at night, could have the bridge and opening clearly defined against the sky or its reflection on the water surface.

This is not the case with the Clinton bridge.

4th. Where the passing boat and bridge are as much sheltered as possible from the most prevailing high winds.

This is as well accomplished by the present location as this vicinity admits of.

5th. Where the current is as gentle as the average of the river affords, and where the piers shall not produce any serious change affecting the regimen of the river.

The Clinton bridge meets these requirements.

6th. Where the most suitable land approaches for the bridge and foundations for the piers can be found.

The Clinton bridge meets these requirements well. The draw should be opened promptly. The Clinton bridge does so.

It is practicable in some cases to find a location that naturally meets all these requirements, and if a bridge is needed where some are not found, then art and labor should be made to supply them. For it is a thing not to be endured that the great navigation interest should suffer a permanent injury in order that a bridge company might be saved a little inconvenience or expense.

The necessity for a safe and reliable transit across the Mississippi River is now so great, that I recognize it as a fact that we can better do without the navigation altogether than to forego the privilege of crossing with certainty at all times and seasons; but this paramount necessity for bridging will produce the means of building even the most costly structures, and all reasonable expense should be willingly made that will leave the navigation practically unencumbered.

I have said nothing about the *width* of draw most proper, as that is regulated by the law. I think, however, that the law requires as great width as is at present practicable. The location of the bridge itself has such an important bearing on this question, that the same spaces would have a far greater practical benefit in a good location than in a bad one, and I think it would have been desirable to have had a permanent commission appointed, composed of men of ability and integrity, that should have approved of every location proposed for a bridge on the Mississippi before a pier should have been allowed to stand in it.

Very respectfully, your obedient servant,

G. K. WARREN,
Brevet Major-General, United States Army.

Hon. ALEXANDER RAMSEY,
Chairman of Committee on Post-Offices and Post-Roads,
United States Senate.

On February 14, 1867, Mr. VAN WINKLE, of the Senate Committee on Post-Offices and Post-Roads, reported on H. R. bill No. 965 (printed report of committee No. 171), recommending its passage without amendment.

On February 21, 1867 (pages 1669–'72 of the debates), the subject was discussed in the Senate.

Mr. VAN WINKLE made a statement of the case, in which he referred to General Warren's report and quoted from it. He said that General Warren was at the place only one day and thought the bridge was in a bad place on account of the curve; that but one draw-opening was available—the one on the Illinois side of the pivot—which was 119 feet wide; the other one was 128 feet wide. He said General Warren was careful in his statements.

Mr. VAN WINKLE favored the bill, because the bridge record showed that of a great number of passages of boats through it there had been

but little injury or loss of time. He further justified his advocacy of the bill, because the right is retained by Congress to alter or amend it at pleasure, thus enabling that body to require such alterations or additional constructions as will obviate all such objections as future experience may show to exist.

Mr. JOHNSON stated the case of the Wheeling bridge, in which he took part as one of the counsel. The United States Supreme Court ordered the bridge to be removed. Congress then declared it a post-route, which the same court held that Congress had the power to do, and that this act took away from the State of Pennsylvania the right to sue. The law was held to be retroactive, and to legalize the structure from the beginning. All suits against it fell at once.

Mr. VAN WINKLE said there was no suit against the Clinton bridge, except one pending for an injunction, commenced by the Northern Line Packet Company. A month's time was given them to offer proof, but they failed to do so.

Mr. HENDERSON thought there was a suit pending, and that the law ought to provide against interfering with pending suits at least. He offered an amendment.

Mr. KIRKWOOD favored the bill. He said General Warren was mistaken in saying the Iowa side of the draw was impracticable; the record shows that nearly half the number of passages under the bridge have been through that side of the draw.

Mr. TRUMBULL favored the bill. He said this bridge, thus constructed, is a part of the great line of railway reaching from the Atlantic to the Pacific Ocean.

Mr. HENDERSON'S amendment was rejected—yeas, 9; nays, 24; absent or not voting, 19.

The bill then passed.

The action of Congress received the approval of the President of the United States, and the bridge became a legalized structure.

A few personal remarks in relation to the debate in the Senate seem called for here. If Mr. VAN WINKLE'S remark "that I was there but one day" (which was a mistake) gave the impression that my examination was incomplete, it was unfortunate. I was there three days with a large surveying party. I also met there, by appointment, Mr. E. B. TALCOTT, the engineer who built the bridge, and gained all the knowledge that could be obtained at that stage of the river.

Mr. VAN WINKLE probably meant to convey the idea that my examination was only at one stage of the river, which was correct.

Mr. KIRKWOOD'S remark was also unfortunate, that I was mistaken in my statement in regard to the draw openings, in which I was unquestionably right. He probably misunderstood my statement, thinking it to refer to the passage on the west side of the island, instead of the west draw-opening.

HISTORY OF BRIDGING THE MISSISSIPPI RIVER AT SAINT LOUIS, MO.

The question of bridging the large navigable Western rivers rises to first importance here, considered from any point of view. It is especially interesting to navigation and engineering, and has received earnest attention from ablest men. An account including the earliest attempts will therefore be given.

Project of Mr. Truman J. Homer, city engineer, his allusions to earlier ones.—In the year 1855 a company was chartered to build a bridge at this place by the legislature of Missouri, under an act entitled—

An act to incorporate the Saint Louis and Illinois Bridge Company.

The company was organized with D. A. January, esq., as president The financial crisis of 1857 and the war of secession deterred the company from further action, and the project lay dormant until 1864, when the legislature passed another act with a similar title. As both these charters had defects, considered in regard to the interests of Saint Louis, an amendatory act was passed in 1864, giving the requisite protection to that interest. This latter was effected through the exertions of a special committee of the board of common council of the city.*

In their report dated February 21, 1865, this committee recommended that the city should memorialize Congress to give authority confirmatory to the act of the legislature of Missouri; "and also that a law be passed, prescribing the form and dimensions, and regulating the construction of steamboats."

This report states that—

> The chimneys and pilot wheels of steamboats may be so constructed as to admit of their being conveniently and expeditiously raised and lowered at will, so as to admit of their passing under an object 35 feet above the surface of the water.

On February 7, 1865, the board of common council instructed the city engineer, Mr. Truman J. Homer, to make a general plan of a bridge, and submit approximate estimates, which he did on the 11th of the same month.

It was for a horizontal tubular bridge crossing the low-water channel in three spans of 500 feet from center of piers at a height 64 feet above low-water mark, or about 30 feet above the city directrix. It was to have a railway in the middle and a wagon-way each side of it. The estimated cost was $3,332,200. The bridge was to cross a few blocks above the existing structure.

Mr. Homer states that Mr. Charles Ellet, upon invitation of the city council in 1839, submitted a project for a suspension bridge crossing at Market street, with one span of 1,200 feet, and two each side of 900 feet, each to cost $700,000; also that Mr. J. W. Bissell made in 1857 a plan for another suspension bridge, with one span of 1,500 feet, and that about the same time Mr. Roebling proposed to erect a bridge with a half-mile span. These proposed suspension bridges were probably for highway only. Mr. Homer was very much opposed to a suspension bridge at this place. For Mr. Roebling's plan for bridge at this place see farther on.

Authorization of bridge by the United States.—On December 4, 1865, Senator B. GRATZ BROWN, of Missouri, gave notice of his intention to introduce a bill for authorizing the construction of a bridge across the Mississippi at Saint Louis. The Senate bill No. 38 (I have not seen a copy of it) was introduced in December and referred to the Committee on Post-Offices and Post-Roads.

Senator RAMSEY, chairman of the Committee on Post-Offices and Post-Roads, reported the bill back with a substitute as an amendment on March 21, 1866, and it was debated on March 22.

Section 2 provided that the bridge might be a pivot or other form of draw, or of continuous span; if the latter, to have an elevation not less than 40 feet above extreme high water, measuring for such elevation from the level of the city directrix to the bottom chord of the bridge; spans to be not less than 250 feet, and piers parallel with the current; if a draw-bridge, must be at the same height, with a span over the main

* Reports of the city Engineer and | special committee | to the | common council | of the | City of St. Louis, | in relation to a | Bridge across the Mississippi River | at St. Louis | — — | St. Louis | McKey, Fishback and Company, printers and binders | 1865.

channel not less than 300 feet, and one adjoining span not less than 220 feet; the draw to be at an accessible and navigable point, with spans not less than 100 feet on each side of the pivot.

In the debate following the reading of the substitute, Mr. BROWN said:

I want the structure when built to be one worthy of the great States it is to connect, of such ample capacity as will permit the transit of the freight of all the railway lines that may hereafter center at the great distributing point of the continent. Let it be built, too, for the ages, of a material that shall defy time and of a style that will be equally a triumph of art and a contribution to industrial development. No narrow view of expense, or contracted idea of the power of engineering skill, should induce us to permit any attempt at bridging the Mississippi River * * * that will seriously interfere with its navigation. The substitute has in certain details of height, measurements, and width of spans, been thought not sufficiently guarded; I have, therefore, submitted amendments *in lieu* of section 2.

They are, in the first place, that the bridge shall be 50 feet in height above high water mark, or what is substantially high water mark, the elevation line of the city directrix. *Second*, have one span 600 feet in the clear, or else two spans 450 feet in the clear each. *Third*, no span over the water-way at low-water mark less than 200 feet in the clear. * * *

From 1860 to 1865, the river did not come up to within many feet of the city directrix. In the last 25 years only three times has the water been above it, 1851, 1858, 1844; on one of these occasions only 3 feet, on another 4 feet, and on the other 7 feet, altogether for a space of 3 or 4 days at each time.

Mr. BROWN'S amendment also provided that the bridge should not be a suspension bridge or draw-bridge, with pivot or other form of draw.

Mr. HENDERSON asked, "Is the amendment substantially in accordance with the recommendation of the Chamber of Commerce of Saint Louis?"

Mr. BROWN answered, "It is exactly in accordance with that, with the simple provision that it substitutes the fixed point of the city directrix for the questionable one of extreme high water."

Mr. HENDERSON remarked, "I was of the impression that the water more generally rose above the city directrix."

Mr. BROWN replied, "No, I have the water-lines for the last 25 years."

The amendment of Mr. Brown was then agreed to.

Mr. DOOLITTLE asked, "Is 50 feet above the directrix sufficient, so as not in any respect to interrupt navigation?"

Mr. GRIMES added to this question, the condition, "Provided they lower their chimneys."

Mr. BROWN replied, "They will have telescopic chimneys. It will not interfere with the pilot-houses, or anything of that sort."

The bill was then passed in the Senate.

Remarks.—It should be noticed here that Mr. Brown's amendment fixing the height of the bridge 50 feet above extreme high water, as recommended by the Chamber of Commerce (which represented the navigation interests), had the effect to put the bridge 7 feet lower than the steamboatmen and navigation interests had consented to. Seven feet above the city directrix, the known height of the high water of 1844, was as fixed a height as the directrix itself. There was nothing uncertain about the extreme high-water mark of 1844. Other floods might not come up so high. Some other floods might go higher.

The navigation interests apparently did not appreciate this change until they saw the first arch about being completed in the summer of 1873. Then they petitioned the Secretary of War to appoint a board of Army engineers to see what could be done, as will be described further on.

The Senate bill No. 38 was received in the House on March 22, 1866,

and on April 2 it was referred to the Committee on Commerce, but I am not aware that it was ever reported back.

In the Senate, on July 17, Mr. RAMSEY, chairman Committee on Post-Offices and Post-Roads, to which Senate bill 236 had been referred, with amendments made by the House, reported it back with an additional amendment.

On July 18 it was considered. This amendment provided for building the bridge at Saint Louis as proposed in Senate bill 38, with the modification requiring that there should be one span of 500 feet in the clear (instead of 600 feet), or two spans of 350 feet each (instead of 450 feet each). This, together with all the House amendments, was agreed to.

On July 21, the House concurred in the Senate amendment. The act was approved July 25, 1866.

Project of the convention of engineers called together by Mr. L. B. Boomer in the summer of 1867.—In 1855, the legislature of Illinois chartered a company to build a bridge across the Mississippi at Saint Louis, styled "The Illinois and Saint Louis Bridge Company." Mr. Boomer, representing this company, of which Mr. A. Anderson was the engineer, called together several distinguished engineers to consider the advisability of building the bridge with one span of 500 feet in the clear, or with two spans of 350 feet in the clear, an option made in the United States law.

The proceedings and report of the assemblage are published in a pamphlet of 100 pages, 8vo, besides three sheets of bridge-strains.*

Mr. William J. McAlpine was chosen president, and Mr. T. McKissock, secretary. In his introductory speech the president said:

> The Federal and State laws under which the bridge is to be built require an elevation sufficient to allow steamers, with their unnecessarily high chimneys, to pass at the highest stage of water, and with spans of unnecessary width for the navigation. "The men of science" must thus far "bow to the men of law," and it is this necessity which has compelled the officers of the bridge company to bring to the consideration of these grave subjects such an array of the "men of science."

Whatever point this remark quoted from Sir Francis Head had when made in regard to the subserviency of men of science to men of law, it seems to be wanting in this case. As shown in the preceding abstract from the Congressional debates, the advocates of the bridge admitted that the chimneys must come down to pass it at ordinary high water, and they only claimed that the pilot-houses would not have to be lowered; but even this was not a bad enough statement for the navigation interest, for on all the large and economical boats the pilot-houses were too high to pass under the bridge at ordinary high water. If the true men of science did "bow to the men of law," it was in having the ability of the scientific engineer underestimated. The man who really stood "cap in hand" was the navigator, appealing for his rights against a rival and unscrupulous interest, and looking to both the man of law and the man of science for protection. The argument of necessity, which knows no law, had been evoked! Bridges must be built! Long and high spans are impracticable! Navigation must give way! said the advocates of poor bridges.

The matter before the convention was divided into five different subjects and submitted to five different committees.

First. On the regimen of the river and the character of its bottom,

* Proceedings and report | of the | Board of Civil Engineers | convened at St. Louis, in August, 1867, | to consider the subject of the construction of a | Railway and Highway Bridge | across the Mississippi River at St. Louis | —.— | St. Louis, | George Knapp & Co., Printers and binders, | 1867.

Messrs. Truman J. Homer, Missouri; J. B. Moulton, Missouri. The report of this committee (seven pages 8vo) contains valuable data on the questions submitted.

Second. On the foundations and piers, Messrs. E. S. Chesbrough, Illinois; William J. McAlpine, New York; General W. S. Smith, Michigan; George A. Parker, Pennsylvania; L. J. Fleming, Alabama; C. L. McAlpine, Massachusetts; and A. Anderson, Kansas. Mr. Chesbrough, the constructor of the lake-tunnel of the Chicago water-works, was chairman; Mr. C. L. McAlpine, constructor of the pneumatic foundations of a bridge across Harlem River, secretary. Of the other members, it may be mentioned that Mr. W. J. McAlpine constructed the dry-dock of the Brooklyn navy-yard, using coffer-dam in 50 feet water, where he also made valuable observations upon the use of common wooden piles. General Smith had sunk the pneumatic foundations for the bridge at Omaha, and on the Savannah River, Georgia, and had experience in several other important and difficult foundation works. Mr. Parker had constructed the very difficult work of making foundations for the bridge over the Susquehanna River at Havre de Grace. Mr. Fleming had also constructed pneumatic foundations on the Santee and Pedee Rivers. This committee thoroughly discussed the subject.

The bed-rock on the west shore is 23 feet below low water; 500 feet east of that, 64 feet; at 500 feet farther east, 90 feet below low water; at 500 feet still farther east, rock had not been found, but boring had only been carried down 68 feet below low water. The great depth at which rock is found, except at the west shore, "induced the consideration of plans of foundation entirely independent of any support to be gained from it, except where it could be reached within a reasonable depth." They regarded a depth of 45 feet below low water as a safe limit of the scour.

At a joint meeting with the committee on regimen of the river and character of bottom and with the committee "on the superstructure and approaches"—

It was unanimously agreed to adopt the minimum spans allowed by the law for crossing the channel * * * as more economical, less hazardous in construction and maintenance, and affording ample accommodation to the commerce of the river and the port of Saint Louis.

These spans were to have horizontal chords. It was also resolved,

That we would recommend spans of less than 350 feet in the clear if the Federal laws permitted such reduction.

The committee estimated that with 350-feet spans and the bridge loaded, the weight on the foundations of a pier, if built solid, would be 8,500 tons. This, if borne by wooden piles, would require 210 of them, each pile supporting 40½ tons.

After a careful consideration of the subject, this committee agreed that the following plans would be entirely practicable:

First. With the piers placed upon foundations of hollow iron piles, on the purely pneumatic principle, either to the rock, or, where it lies at too great depth, by an expansion of their base, or driven by the use of sand or steam siphon-pumps.

Secondly. With piers of masonry carried below the scour of the river by the use of iron caissons, as was practiced at the different piers of the Susquehanna Bridge, and resting either on wooden piles or small pneumatic piles.

Thirdly. With piers of masonry carried below the scour by the use of a combination of inverted and direct iron or wood caissons; the inverted caisson filled with masonry by the pneumatic process and the direct caisson in the ordinary way.

Fourthly. With the piers laid up either of solid or galleried masonry.

Fifthly. That instead of masonry, the iron pneumatic piles may be extended upward to the bridge-seat as columns of support, and strongly braced on the lines of the river and the axis of the bridge.

The third committee was on "the superstructure and approaches." This was composed of Messrs. S. S. Post, of New Jersey; R. M. Shoemaker, of Ohio; L. J. Fleming, Alabama; O. Chanute, Kansas; T. B. Blackstone, Illinois; and William J. McAlpine, New York.

The design of superstructure they estimated for was trusses of Mr. Post's pattern, four of them per span, having a single-track railroad, two highways 17 feet in the clear, and two sidewalks outside of the whole.

It was decided at a joint meeting of the committees to adopt the two spans of 368 feet from centers or 350 feet in the clear, next the Saint Louis side, and to place four spans of 264 feet from centers between them and the Illinois shore. A single span on each side was to carry the bridge over the levees on each side.

It is stated in this report that spans 500 feet in the clear will cost more than twice as much per foot as for 350 feet in the clear. These estimates were for a bridge with a moving load of about 7,300 pounds per foot. The cost of the superstructure and approaches was estimated at $3,638,920.

The fourth committee, on the commerce and navigation, consisted of Messrs. T. J. Homer and F. A. Churchill, Missouri. Their report is embodied in the general report of the convention.

The fifth committee, on the commerce crossing the bridge, was composed of Messrs. T. B. Blackstone, Illinois; A. Anderson, Kansas; T. McKissock, Missouri; and Charles A. Tucker. This committee made a special report of four 8vo. pages. Mr. Tucker did not sign the general report.

The principal features of the committee reports were accepted and embodied in a general report consisting of fourteen pages, 8vo. The bridge was to cross a few blocks above Washington avenue, in Saint Louis. The estimated cost of the whole work as adopted in the general report was as follows:

For land damages	$336,000
Foundations, piers, and masonry	2,541,007
Superstructure and approaches	3,638,920
	6,565,927

From the report and proceedings it does not appear that any engineers took part in the deliberations other than those named above as serving on committees. All their names are attached to the general report, and, in addition, the names of thirteen others, being all those named in the printed report after the name of Mr. S. S. Post.

PROJECT FOR BRIDGE BY CAPT. JAMES B. EADS, SUBMITTED TO THE BRIDGE COMPANY IN MAY, 1868.

The bridge company authorized by the legislature of Missouri and the one authorized by the legislature of Illinois were united under the title of the Illinois and Saint Louis Bridge Company, and Capt. James B. Eads was appointed engineer-in-chief.

The first of his reports that I have seen consists of 72 pages, 8vo. with one map of the locality and perspective view, with several woodcuts illustrative of principles governing the construction of bridge-spans, as well as representations of several of the most celebrated bridges in the world.*

* Report | of the | Engineer-in-chief | of the | Illinois and St. Louis | Bridge Company, | St. Louis, May, 1868. | St. Louis | Missouri Democrat book and job printing office, corner of Fourth and Pine Streets, | 1868.

This is accompanied by an appendix containing 77 pages, 8vo, separately paged, being "Mathematical Investigations and Computations for the Construction of the Illinois and Saint Louis Bridge.—Missouri Republican Print." This has some small diagrams and three sheets of diagrams.

Captain Eads was assisted by Col. Henry Flad, Civil Engineer, and Mr. Charles Pfeifer. The mathematical work was verified by Prof. C. W. Chauvenet, LL. D., &c.

The report is an interesting and instructive contribution to the bridge literature of the period. It at length discusses the report of the civil engineers made the year before, and rejects their conclusions. The bridge proposed in Captain Eads's report "will have three spans each formed with four ribbed arches, made of steel. The center span will be 515 feet and the side ones 497 feet each in the clear."

I will not copy the details of the design from this report, as they were modified and improved upon in the report to the bridge company made in October, 1870. It was designed for two separate railway-tracks, to allow of passing both ways at once, and above this a roadway for ordinary vehicles and street-cars, 34 feet wide, and two sidewalks, each 8 feet wide. The service required of it was therefore very large. The greatest load was calculated to be $7\frac{2}{10}$ tons per linear foot, including its own weight, which was 4 tons per linear foot.

The design was claimed to be one of great economy over any other form of bridge that would afford the same service; the total estimate of cost was as follows:

Superstructure	$1,460,418 30
Substructure	1,540,080 00
Approaches	520,397 24
Tunnel	410,477 55
Land and land damages	539,900 00
Railroad	25,680 00
Total	4,496,953 09

The work on the Saint Louis abutment was begun in 1867, a coffer-dam having been constructed, and excavation carried to the bed-rock upon which the masonry was laid. About 1,040 cubic yards had been laid by the 15th of March, 1868, bringing the work up about 12 feet above low water, when work was arrested by the rising of the river.

By act of Congress approved July 20, 1868, the consolidation of the two bridge companies was sanctioned, and the privileges conveyed in the act approved July 25, 1866, were granted the new company, and it was also made obligatory to build one span at least 500 feet in the clear.

USES MADE OF THE REPORTS ON THE SAINT LOUIS BRIDGE TO INFLUENCE CONGRESSIONAL LEGISLATION IN REGARD TO BRIDGING THE OHIO RIVER.

In the spring of 1868, a bill was introduced in Congress, to authorize building a bridge at Paducah, and another to extend the provisions of the act of July 14, 1862, authorizing the Steubenville bridge (which was general in its application as far down the Ohio as the mouth of the Big Sandy), so as to authorize a bridge of the same spans anywhere above the mouth of the Licking River. This last provision was made especially to benefit the interest contemplating the construction of a railway and highway bridge between Cincinnati, Ohio, and Newport, Ky. Great interest was at once aroused on the subject, and many petitions, memorials, &c., were addressed to Congress. The navigation interest con-

tended for a clear span of 500 feet, and not only opposed the extension of the law authorizing the Steubenville bridge, which required a clear span of only 300 feet, but endeavored to have it repealed altogether. In the last effort they were opposed by the interest of the Baltimore and Ohio Railroad Company, who were about to build bridges under this law at Bellaire and Parkersburg.

The Senate Committee on Post-Offices and Post-Roads were instructed to report a general bridge law, and the chairman sent for me to aid him in its preparation. I then made an examination of the Steubenville bridge, and submitted on estimate of cost for a single-track railway, having a clear span of 500 feet, and two adjoining of 300 feet, at about $800,000. The object of this was to show that their cost would not render them impracticable, for the estimated cost of the bridge at Saint Louis, about $4,500,000, by Captain Eads, and about $6,500,000 by the convention of engineers, had placed a strong argument in the hands of the opponents of long-span bridges, who concealed the fact that these estimates were for kinds of bridge providing for quadruple the service of a single-track railroad.

The whole subject is fully set forth in the report of the committee dated July 16, 1868 (Rep. Com. No. 168, Fortieth Congress, second session), and they submitted a bill requiring 500-feet spans.

This proposed law was discussed in the Senate on July 21, and strong objection was made to it, on the ground that 500-feet spans were impracticable, and this was enforced by citing especially the report of the convention of civil engineers on the Saint Louis bridge. A small pamphlet with extracts from that report was printed, and distributed to members of Congress. No final action was taken that session in regard to the general law.

A kind of compromise was made with regard to the Newport and Cincinnati bridge, which, however, was deceptive, and occasioned much future trouble. Believing that the report of the civil engineers convention at Saint Louis was being made to subserve ends never intended by its framers, I addressed a circular letter to the signers of that report. Answers, containing much information, were received from twelve of them, and one of them sent me also a communication of much interest from General C. Shaler Smith, civil engineer.

This circular and the letters are given in order following:

Circular.

UNITED STATES ENGINEER'S OFFICE,
Saint Paul, Minn., December 21, 1868.

Member of a Convention held at Saint Louis in August, 1867.

GENTLEMEN: I respectfully request your consideration of the use that has been made of your report in a pamphlet circulated among members of Congress at the last session, and would like to be informed by you, individually, how far you intended to decide the question of bridging the great navigable Western rivers. It did not seem to me that anything more was intended by the convention than to "recommend to the parties in interest," viz, "the bridge company," what you deemed was for their interest, and I think that may be clearly inferred from your report. Nevertheless, there are expressions used in different places in it which seem to indicate that the conclusions reached were general in their application, and I have thought it best to refer the matter to you. I have taken from the pamphlet to which I call your attention its title-page, and all there is quoted from your report.

In order that you may understand why it is that *I* bring this matter before you, I will state:

That in August, 1866, I was assigned to the duty of collecting information in relation to bridging the Mississippi River between Saint Paul, Minn., and Saint Louis, Mo., under a joint resolution of Congress passed just previous to my being thus assigned. I have been engaged upon this, with other duties, ever since, reporting progress from

time to time to the Chief of Engineers, United States Army, and conferring and communicating with the Senate Committee on Post-Offices and Post-Roads at each session.

At the last session, the question of bridging the Ohio River was brought prominently forward, and I was consulted by this same committee in relation thereto. The report of this committee you can probably obtain by writing to a member of Congress. It forms printed Senate Report Committee No. 168, Fortieth Congress, second session.

The substance of what I am responsible for in that report is, that a 500-feet span (not a suspension one) is practicable, and, with the contiguous spans of the ordinary length, with single track, at an expense not greater than for such bridges already built in this country, and that the interests of the navigation should determine whether such long spans were necessary, as it might be in some cases and not in others. I did not think then that I was at variance with the Saint Louis convention; that convention had decided the question as far as it related to the bridge company's interest, and to the effect, that the cheaper the bridge the better for them, while I had given my opinion that the necessities of navigation should decide it, provided these were not so exacting as to be practically prohibitory to bridges.

The debates on the subject in the Senate on July 16, 17, 21, and 22 (see Globe), show that very considerable importance was given, in the minds of some members of the Senate, to the extracts from the report of the Saint Louis Convention, one Senator using the following language: "I wish to read a few extracts from a longer report now in the hands of the Senator from Indiana. As we cannot get any other reports to know whether this [the report of the Senate committee] is right or wrong, I shall be inclined to rely on this report of 25 civil engineers, one of them, however, being from the United States Army." Extracts were then read from this pamphlet, and the Senator concluded: "Mr. President, I am bound to believe, until I see something to the contrary from some authoritative source, that this idea of a 500-feet span is a mere notion, gotten up by one opposing interest against another."

I hope you will not take this reference of the matter to you, by me, as an unwarrantable intrusion. I would be obliged to you for such answers as you choose to make, and I would like to have them sent me with the understanding that they may be officially used by me in my reports.

I, myself, attach the highest value to the decision of a body composed of such distinguished engineers as composed that convention, and as it is not a permanent organized body, I have addressed this to you individually. The weight which your decision must carry with it must be my excuse for endeavoring to ascertain "authoritatively" what that decision practically was, and its extent and application. The question has not yet been disposed of in Congress.

Yours, respectfully,

G. K. WARREN,
Major of Engineers, Brevet Major-General, United States Army.

The following are the extracts from the report of the convention as published in the pamphlet:

FACTS RELATING TO THE BRIDGE QUESTION.

300-feet span sufficient and safe, and fixed by Congress for the Ohio River—500-feet span hazardous, and an untried experiment—Suspension bridge prohibited by Congress at Saint Louis—Opinions of eminent engineers and bridge-builders—Towage on the Ohio River—Bradley & Power, printers, 149 Main St., Cincinnati, O., 1868.

Convention of Engineers at Saint Louis.

[Extracts from the proceedings and report of the board of civil engineers convened at Saint Louis in August, 1867, to consider the subject of the construction of a rail and highway bridge across the Mississippi River at Saint Louis.]

The following persons took part in the proceedings of the convention, and signed the report, in which they all concurred. Report, pages 90, 91.

WM. J. MCALPINE, Civil Engineer, New York.
GEORGE A. PARKER, Civil Engineer, Pennsylvania.
E. S. CHESBROUGH, Civil Engineer, Illinois.
W. S. SMITH, Civil Engineer, Michigan.
L. J. FLEMING, Civil Engineer, Alabama.
A. ANDERSON, Civil Engineer, Kansas.
C. L. MCALPINE, Civil Engineer, Massachusetts.
T. J. HOMER, Civil Engineer, Missouri.
J. B. MOULTON, Civil Engineer, Missouri.
T. B. BLACKSTONE, Civil Engineer, Illinois.

1. McKissock, Civil Engineer, Missouri.
R. M. Shoemaker, Civil Engineer, Ohio.
O. Chanute, Civil Engineer, Kansas.
F. A. Churchill, Civil Engineer, Missouri.
S. S. Post, Civil Engineer, New Jersey.
R. B. Mason, Civil Engineer, Illinois.
Julius W. Adams, Civil Engineer, New York.
W. E. Merrill, Brevet Colonel United States Engineers.
Wm. E. Worthen, Civil Engineer, New York.
John E. Henry, Civil Engineer, Iowa.
S. F. Johnson, Civil Engineer, Rhode Island.
L. H. Clark, Civil Engineer, Illinois.
Jas. H. Morley, Civil Engineer, Missouri.
E. H. Johnson, Civil Engineer, Illinois.
W. W. Evans, Civil Engineer, New York.
F. Hubbard, Civil Engineer, New York.
D. C. Jenne, Civil Engineer, New York.
Ira Spaulding, Civil Engineer, New York.

The objects of the convention, and the class of men of whom it was composed, will appear from the following passages in the opening address of the president, William J. McAlpine, of New York, the oldest practicing civil engineer in the United States (Report, pp. 4, 5, 6, and 7):

"The problem which is presented to us is not only one of the most interesting ones of the profession, but also involves other considerations of the highest commercial importance.

"In preparing plans for bridging the Mississippi we must give due attention to the relative importance of the navigation of the river, and of the traffic which the bridge is to accommodate. The former is one of the most important inland water-channels in the world, and the latter is to form a connecting link in one of the most important lines of land transport across the continent.

* * * * * * *

"'Heretofore the traditional importance of the navigable water lines has controlled legislation and the legal tribunals almost wholly in their favor. The last third of a century has developed a traffic over the land lines of transport of such importance that modern legislation and legal decisions have been compelled to concede the right to carry railroads across the navigable waters; and although this legislation has not yet risen to the correct view of the question (namely, that they should each yield and have the right of occupancy in proportion to their relative importance), yet it has made such progress that, as Sir Francis Head not long ago said in regard to the Britannia bridge, 'the man of science must no longer, cap in hand, bow to the man of law.'

"The Federal and State laws, under which the bridge at this place is to be built, require an elevation sufficient to allow steamers, with their unnecessarily high chimneys, to pass at the highest stage of water, and with spans of unnecessary width for the navigation. 'The men of science' must thus far 'bow to the men of law,' and it is this necessity which has compelled the officers of the bridge company to bring to the consideration of these grave subjects such an array of the 'men of science.'

"Although we have been convened at the request of one of the rival companies, yet we are to consider all of the questions bearing on this subject without reference to any particular plan or company. We have among our numbers the pioneer of the pneumatic pile foundations and his eminent successor; the constructor of the caisson-built piers of the Susquehanna; the builder of the Lake Michigan tunnel; the veteran bridge-builder who has made the longest wooden span in the country, and has now presented us with designs of those in iron, to meet even the requirements of the 'men of law.'

"We have with us eminent representatives from our great national polytechnic, and from our highest civil universities, and I may venture to say that the result of our deliberations is looked forward to with great interest by those both in and out of the profession, and that the belief is strongly entertained by the commercial, financial, and professional gentlemen interested in this and similar enterprises that your combined science and skill will develop the best method of overcoming the difficulties to be met in accomplishing this great undertaking.

* * * * * * *

"From such an array of engineering talent we may expect a complete elucidation of the important questions before us.

* * * * * * *

"The law requires a bridge to be constructed with one of its spans not less than 500 feet clear opening, or with two spans of not less than 350 feet each.

"You will be called upon to consider whether the saving to be effected by the cost of the foundation and piers will be equal to the increased cost of the superstructure in

spans of such great length, and whether suitable materials can be procured and put together so as to sustain their own weight and those of stationary and passing loads."

For the purpose of facilitating the business before the convention, a resolution was adopted requesting the chair to appoint committees on the following subjects (Report, p. 8).

1. On the regimen of the river and the character of its bottom.
2. On the foundations and piers.
3. On the superstructure and approaches.
4. On the river commerce and its navigation.
5. On the commerce crossing the bridge.

[Extracts from the minutes of the proceedings and discussions of the committee on foundations and piers.]

It was decided that the discussions should be with open doors, and that any member of the convention, or any person interested in the subject who expressed a desire to that effect, should be invited to be present during the discussions (Report, p. 19.)

And the committee, in conjunction with the committee on the regimen of the river, having had the subject referred to them under consideration for two days, their further proceedings were as follows (Report, pp. 34 to 36):

LENGTH OF SPAN.

The further consideration of the questions involved in the construction of the proposed bridge requiring consultation between the committee on the regimen of the river and that on superstructure, and in order that some of the general points affecting the calculations of each of the committees might be agreed upon, a conference was therefore had with the two committees named, and a joint meeting was held to consider these points, consisting of the following-named gentlemen:

T. J. Homer, J. B. Moulton, H. C. Moore, E. S. Chesbrough, W. S. Smith, George A. Parker, L. J. Fleming, A. Anderson, C. L. McAlpine, S. S. Post, R. M. Shoemaker, O. Chanute, T. B. Blackstone, W. J. McAlpine.

The chairman of the committee on superstructure having made elaborate drawings, estimates, and descriptions of plans, and having placed them all before the joint committee, the members thereof proceeded to discuss the general subjects, and to compare the results of the other experiences applicable to the case so far as to satisfy themselves that the calculations, &c., referred were substantially correct and sufficient to enable them to proceed with the further general consideration of the questions involved, which were presented by Mr. McAlpine, as follows:

1st. Of the two alternatives for the spans for the main channels allowed by law, which should be adopted?

2d. What spans (within the limits of the law) are best for the remainder of the distance?

3d. What dimensions and accommodations of the bridge are necessary for the convenience of its traffic?

4th. What will be the approximate cost on the basis which shall be decided, in reply to the foregoing propositions?

And the following preamble and resolutions were agreed upon:

Whereas the Federal law authorizing the construction of the bridge across the river at Saint Louis requires, as per section 12, as follows:

"SEC. 12. *And be it further enacted*, That the bridge authorized by the preceding section to be built shall not be a suspension bridge, or a draw-bridge with pivot or other form of draw, but shall be constructed with continuous or unbroken spans, and subject to these conditions: First, that the lowest part of the bridge, or bottom chord, shall not be less than fifty feet above the city directrix at its greatest span. Second, that it shall have at least one span of five hundred feet in the clear, or two spans of three hundred and fifty feet in the clear of abutments. If the two latter spans be used, the one over the main steamboat-channel shall be fifty feet above the city directrix, measured by the lowest part of the bridge at the center of the span. Third, no span over the water at low-water mark shall be less than two hundred feet in the clear of abutments";

And whereas the said law confines the question of the span over the main channel to one of five hundred feet, or two of three hundred and fifty feet each (clear width);

And whereas by careful calculation, the amount of the materials and the cost of that portion of the bridge above referred to, arranged on the most judicious and economical spans for the remainder of the distance, will involve an extra cost of about three-fourths of a million of dollars;

And whereas there has been no bridge of the character of that which (in our judgment,) is required in this place yet constructed, to furnish us with any reliable and cer-

tain data on the serious questions of materials and workmanship in spans of such great length: It is, therefore,

Resolved, That we, as practical engineers, cannot conscientiously recommend to the parties in interest to venture upon the construction of spans of as great length as the maximum one prescribed by law, and that therefore we do recommend for adoption the minimum spans allowed by the law, as more economical, less hazardous in construction and maintenance, and affording ample accommodation to the commerce of the river at the port of Saint Louis.

It was also

Resolved, That, in view of all the circumstances of this case, we would recommend spans of less than 350 feet in the clear, if the Federal law permitted of such reduction.

[Extracts from the report of the committee on the foundations and piers.]

At the joint meeting of the committee, and those on the regimen of the river and superstructure, it was unanimously agreed to adopt the minimum spans allowed by the law for crossing the main channel, namely, two of three hundred and fifty feet each in the clear; and the following preamble and resolutions were agreed upon (the preamble and resolutions previously quoted, Report, p. 42.)

* * * * * * *

The committee examined the estimates of the chief engineer as to the cost of the foundations and piers, and are satisfied that they will be sufficient in amount.

* * * * * * *

A careful revision of the details of the chief engineer's estimate satisfies the committee that a sufficient sum in gross has been arrived at to amply cover the cost of the foundation and piers, upon either of the plans which have been recommended by it for adoption at this place. The aggregate amount for these items is $2,541,007.

In conclusion, the committee would say that in their deliberations they have been influenced by strong professional interest in a work whose magnitude demanded of them the best knowledge, consideration, and judgment that could be applied to it.

* * * * * * *

Many of the committee were notified at an early day that this question would be brought before them, and at the meeting it was found that much individual examination of the subject had already been made, assisted by the practical experience which they had gained in the construction of their works. In committee, therefore, a varied and comprehensive knowledge was developed, which greatly assisted in the solution of the difficulties to be met with at this place, and it enabled the members, after free discussion, to arrive at results with great confidence (Report, pp. 44, 45.)

[Extracts from the report of the committee on superstructure and approaches.]

The further consideration of this subject involves a knowledge of the regimen of the river at this place, and of the foundations of the piers. Therefore, the committee on this subject requested a joint meeting of those to whom these questions had been referred. Such a meeting was held, and after an elaborate discussion of the whole subject it was unanimously resolved by the members of the joint committee "That, under the circumstances of the case, it is expedient to construct the spans over the main channel of 350 feet in the clear," and they expressed by resolution "their unqualified disapprobation of spans of 500 feet." The joint committee also recommended the arrangement, above described, of spans of 364 feet between the main channel and the east shore.

It was proved in joint committee that the cost of a span of 520 feet (500 feet in the clear) will be more than twice as great per foot of bridge as a span of 368 feet (350 in the clear) and not less than three times as great as a span of 304 feet; consequently, the cost of one span of 520 feet will be equal to two spans of 368 feet and one and a half spans of 264 feet; that is, for the cost of one span of 520 feet no less than 1,150 feet of bridge in spans of 368 feet and 264 feet may be built (Report, p. 48.)

The committee give the results of elaborate estimates of the weight of the bridge, and the loads it will have to sustain, and of the consequent strains that will come on its several parts; and conclude as follows:

"Detailed and close estimates have also been made of the quantities and cost of material required to fully meet all the strains as thus computed, which detailed estimates have been placed at the disposal of the Illinois and Saint Louis Bridge Company, amounting in the aggregate to $3,638,920. This sum, however, includes, besides the superstructure of the bridge as above described, a span of 160 feet, single track, across Cahokia Creek, the embankments of earth forming the approach, paving the carriageways, flagging the sidewalk of the approaches, and 6,000 feet of railway-track. It is, in other words, the cost complete of that part of the work referred to this committee (Report, p. 54.)

[Extracts from the general report of the convention.]

The joint committee on the regimen of the river, on the foundations and piers, and on the superstructure, discussed the alternative proviso of the law in regard to the

length of the spans across the main channel, and unanimously agreed that it was inadvisable to adopt the span of five hundred feet clear opening, on account of the difficulty of procuring suitable materials of the proper form, size, and workmanship required to meet the extraordinary strains to which some of the members of the truss would be subjected; the increased hazard of its construction and maintenance; the large additional cost of the whole structure by the use of the long span, and because the necessities of this case do not require the use of one of such great length, for which there is no engineering precedent.

The joint committee, therefore, adopted the alternative of two spans of 350 feet clear width over the main channel, and spans of 264 feet over the remainder. The board entirely concurred in the conclusion of the joint committee (Report, p. 79.)

The report of the committee on the river commerce and its navigation is embodied in the general report, and the following paragraphs are copied from it (Report, pp. 85, 86, 87):

"In times gone by, before lines of railway radiated in every direction, making a rapid and sure conveyance to all parts of the country, it might have been urged with much force that everything which tended to retard the river navigation was a matter of public importance and to be protested against. But now the case is entirely different; we no longer look to steamers as a means of passenger conveyance; as a general thing, even pleasure travel usually takes the mode of quickest transit from point to point.

"Time is the great element which governs all our actions, and the want of it is such a peculiarly American characteristic, that the man who should propose a business trip to Saint Paul, Cincinnati, or New Orleans by water would be considered a little short of insane.

"One of the immediate and principal effects of bridging the Mississippi at this point is thought to be the establishment of a line of demarkation between the upper and lower river trades.

"As the class of steamboats adapted to the lower river are quite different from those on the upper river, we think this result a natural consequence, and from the nature of things very likely to follow. This would do away with the necessity of constantly passing the bridge, and hence remove a great objection generally urged against the erection of similar structures in navigable waters; but we venture to say that the pilot who could not see so plain a monument as a pier 85 feet high and 12 to 18 feet wide at the smallest point, would hardly be able to get a license to navigate rivers where myriads of snags rear their pointed crests for a distance of 3,000 miles at a stretch.

"We propose, however, to show that the bridge is well adapted to the wants of the river marine.

"Let us take the dimensions of some of the largest of the various classes of boats plying on the river."

The report gives the dimensions of a number of steamboats, varying from 235 feet length over all by 61 feet breadth of beam over all, to the *Great Republic*, the largest steamer afloat on the Western rivers, which measures 336 feet length over all by 96 feet breadth of beom, and proceeds as follows:

"The principal spans, as determined by the law of Congress, are established at either 500 feet or 350 feet; now, a comparison of the foregoing data with these lengths of span shows that the largest boat on the river would not occupy one-quarter of the width of even the smallest span allowed by law, or with a tow of barges less than one-half the width.

"We think there can hardly be a doubt in the mind of any intelligent man but that the span of 350 feet is abundantly large to enable a free and unrestricted passage at all times.

LETTER OF MR. JULIUS W. ADAMS, CIVIL ENGINEER.

WALLABOUT IMPROVEMENT COMMISSION,
OFFICE OF CHIEF ENGINEER,
City Hall, Brooklyn, January 7, 1868.

SIR: Your circular of date December 31 is received. In reply, I would beg leave to say, prior to the publication of the proceedings of the Saint Louis convention of engineers (in the deliberation of which I took no part, not having been present), I received from the president of the bridge company, with whom I was personally acquainted, a printed pamphlet of 14 pages, purporting to be the report of the board of engineers, convened at Saint Louis, with the request that if I concurred in the statements therein made, I would sign the paper and return it to him, which I did. I subsequently received the published proceedings of the convention, and found that the paper to which I refer constituted a part of it, viz, from page 77 to 90. On page 79, the third paragraph embodies my views as regards the proper length of span to be adopted in this instance.

I should remark that, so far as I know, no form of bridge came up for discussion before the convention, save the horizontal chord trussed-frame bridge of Mr. Post.

In May of this year, Mr. James B. Eads laid before me the plans, estimates, and calculations for a 500-feet-span steel arch bridge, prepared by him at Saint Louis, with the request that I would give my opinion of its stability, &c.

After due deliberation, I unhesitatingly reported *in favor of the project*, with such modification of detail as occurred to me as desirable, *not affecting the length of span, however.*

I mention this to show that I by no means considered my opinion as having previously been expressed as adverse to spans of 500 feet, or *even greater*, and that Captain Eads so understood my views is shown by the fact of submitting his plans for my approval.

Very respectfully, your obedient servant.

JULIUS W. ADAMS.

Major-General WARREN,
United States Engineers.

LETTER OF MR. DANIEL C. JENNÉ, UNITED STATES CIVIL ENGINEER.

UNITED STATES ENGINEER'S OFFICE,
DES MOINES AND ROCK ISLAND RAPIDS IMPROVEMENTS
AND ILLINOIS RIVER SURVEY,
Keokuk, Iowa, January 7, 1869.

GENERAL: Your circular of December 21, 1868, was duly received. In reply, would say that I was not present at the convention of civil engineers held at Saint Louis in August, 1867, although my name appears attached to the report of the proceedings.

Therefore I cannot give a definite answer to the question proposed in your circular, but my understanding of the matter is that reference was particularly had to the construction of the bridge across the Mississippi River at Saint Louis, yet it might refer to the general question of bridging important navigable rivers.

Respectfully, your obedient servant,

DANIEL C. JENNÉ,
United States Civil Engineer.

Bvt. Maj. Gen. G. K. WARREN,
Major of Engineers.

LETTERS OF MR. A. ANDERSON, CIVIL ENGINEER.

1.

UNION PACIFIC RAILWAY, EASTERN DIVISION,
OFFICE OF THE GENERAL SUPERINTENDENT,
Lawrence, Kansas, January 8, 1869.

MY DEAR SIR: Your letter from Saint Paul came during my absence at the East, as well as your circular.

To the latter I have made the reply inclosed, which seems to cover the points of the case.

I do not see how the resolution adopted by the convention can be reasonably construed to have the meaning attributed by the author of the Cincinnati pamphlet, although it was loosely worded, and its phraseology was objected to by some of the parties present. * * *

Truly, yours,

A. ANDERSON.

Maj. Gen. G. K. WARREN,
United States Engineers, Washington, D. C.

2

UNION PACIFIC RAILWAY, EASTERN DIVISION,
OFFICE OF THE GENERAL SUPERINTENDENT,
Lawrence, Kans., January 8, 1869.

GENERAL: Your circular is received, asking of me, as a member of the convention of civil engineers, held in Saint Louis in August, 1867, how far it was intended by that convention to decide the question of bridging the great navigable Western rivers.

In reply, I would state that the general question of proper length of spans was not discussed by the convention, or brought before it in any way; neither was the practicability of constructing bridge spans of 500 feet long or more.

The subject before the convention was, whether it was better to construct a bridge over the Mississippi River, at Saint Louis, with openings of 500 feet, or to adopt the

shorter spans of 350 feet, allowed by the act of Congress authorizing the bridge to be built.

As chief engineer of the bridge company, upon whose invitation the convention assembled, I had recommended constructing the shorter spans, and after an exhaustive examination, embracing all points of commercial as well as engineering interest, the convention unanimously recommended the same.

The phrase in the adopted resolution, "parties in interest," referred only to the bridge company.

I regard the proper width of opening in any bridge over the great rivers as dependent upon the circumstances of each individual case, taking into consideration the wants of navigation and engineering characteristics of the location, and would not hesitate to recommend and construct spans of 500 feet opening, or longer, if the situation made them advisable.

Very respectfully,

A. ANDERSON,
Civil Engineer.

Maj. Gen. G. K. WARREN,
United States Engineers, Washington, D. C.

LETTER OF MR. O. CHANUTE, CIVIL ENGINEER.

ENGINEER'S OFFICE, KANSAS CITY BRIDGE,
Kansas City, Mo., January 8, 1869.

MY DEAR SIR: I am in receipt of your circular under date of December 21, 1868, to members of the Saint Louis bridge convention, inquiring how far I understand their action to have been intended to decide the question of bridging the great navigable Western rivers.

The convention was called, as you are aware, by one of the companies proposing to bridge the Mississippi River at Saint Louis, to examine and report upon the practicability, efficiency, and economy of the plans and estimates previously made by their engineer, A. Anderson, esq., which were submitted to the convention.

As the problem of bridging any of our great rivers would be varied at each point by the circumstances of location, the amount of traffic to be accommodated both on the bridge and the river, and the character and class of the navigation, I think I must express nearly the unanimous sense of the convention in stating that its proceedings were designed to apply merely to the bridging of the Mississippi at Saint Louis.

The law of Congress presented two alternative arrangements over the main channel: either one span of 500 feet or two spans of 350 feet each in the clear. It was understood that a rival company proposed to adopt the 500-feet span, while the plans of superstructure which were submitted to the convention were for beam-trusses, the construction of which, as well as the methods proposed for putting in the foundations, we found to be practical and efficient.

Under these circumstances we did not attempt to suggest any new plans, and recommended the adoption of the alternative, of the two spans 350 feet long, as being the cheapest arrangement, the quickest and safest to erect, and in our judgment sufficient to answer the requirements of navigation at that point. It was understood in discussing the resolutions that it was perfectly practicable to build spans of 500 feet, but that they would be very costly, and that a mistake in plan, material, or workmanship would be far more disastrous than in shorter spans. Several of the engineers present were understood to be prepared to undertake their erection should the circumstances of the case require it and capital be forthcoming for that purpose.

I regret, in common with every member of that convention which I have met since its close, that we allowed resolutions to pass so loosely worded as not to convey clearly our meaning, so that while they could be used by one bridge interest in a manner never contemplated by us, they were justly open to the adverse criticism of another.

Allow me, however, to suggest in conclusion, that the general question of bridging our great rivers, could scarcely be expected to be glanced at, much less (with so progressive a science as engineering) settled in a four days' session. It seems to me that such a problem may perhaps be best solved by prohibiting certain designs such as suspension and draw-bridges of *any* length, or by any inflexible rule as to spans and heights, extending over any considerable part of the course of even a single river; but that it would perhaps be best to let the local requirements and circumstances govern each case. An arrangement which may be found efficient on the Upper Mississippi would probably prove a great nuisance at Saint Louis, and be utterly impracticable at Memphis, or New Orleans, and each bridge should be so arranged that the local navigation can safely pass with ordinary care at all times.

On the other hand, while the requirements of the river commerce should be fully guarded and preserved, it seems wasteful that bridge companies should be required to incur what may be needless expense, and sink capital in providing greater accommo-

dation than is really needed. Long spans, upon any design, are expensive and hazardous; that to require them without the clearest necessity might make the building of bridges so onerous as to deter capital from undertaking works of great public importance.

Very respectfully.

O. CHANUTE.

G. K. WARREN, Esq.

LETTER OF MR. W. E. WORTHEN, CIVIL ENGINEER.

63 BLEECKER STREET,
New York, January 9, 1869.

DEAR SIR: In answer to your circular, I did not attend the Saint Louis convention nor did I understand that by the tacit permission of my name to the report I indorsed 500 feet as the limit of span for a bridge not suspension; in fact, at about the same time I had recommended to an engineer friend that he should adopt the truss and brace for a span of about 750 feet, rather than suspension, as being probably the cheaper and better in the position in which this bridge was to be constructed. In my railway experience I have never had charge of the construction of bridges of over 200 feet span, nor should I adopt any longer than this if cost and position permitted; but if the circumstances of locality and economy of construction and maintenance were in favor of a span of 750 feet, as above recommended by me, I should have no hesitation in adopting it.

I am yours, truly,

W. E. WORTHEN.

Maj. Gen. G. K. WARREN.

LETTER OF MR. E. S. CHESBROUGH, CIVIL ENGINEER.

CHICAGO, *January* 16, 1869.

DEAR SIR: Your circular of December 21 did not reach me until quite recently.

I spent but two days at the Saint Louis convention and did not draw up the report; nevertheless having signed it, I will not attempt to evade the responsibility attending that act.

In my own mind, the great object of the convention was to advise the bridge company what to do with regard to the adoption of plans. I should be very sorry to say it was impracticable to build a truss-bridge, safe for railway traffic, with a span of 500 feet, or even of 600 feet, but I do think it would be very unwise to attempt either where the circumstances of the case did not make it absolutely necessary. My own experience and observation would lead me to adopt spans of much less length than 500 feet where it could be done without too great a sacrifice in other respects.

The time even the Kuilenburg bridge has been built and tried by such trains as run on American roads, has not been sufficient, in my opinion, to pronounce it a safe precedent in cases where such a length of span could be avoided.

Yours, very respectfully,

E. S. CHESBROUGH.

General G. K. WARREN,
United States Army.

LETTER OF MR. FRED. A. CHURCHILL, CIVIL ENGINEER.

SAINT LOUIS, *January* 25, 1869.

DEAR SIR: Your circular dated December 21, 1868, was received in due time, and has had my attention.

I firmly believe that river navigation must in the future give ground to railways more rapidly than ever, and thinking thus, I believe that the most economical bridge structure consistent with the requirements of the location is the best. Therefore, it seems to me that 350 feet is ample for the necessities of the river commerce at this point. A larger span would not, in my opinion, benefit the navigation much, if any, while it would increase very greatly the cost of the bridge.

Of course the peculiar circumstances attending the location of each bridge must weigh greatly with the engineer who has to decide upon the span and other details; and while I am in favor of a medium span at this particular point, being as it were a terminus for the upper and lower river boats, I am in favor of stretching to the utmost limit consistent with safety the spans of all bridges over the great rivers which cross at points intermediate to the large cities along their banks. The character of boats navigating that particular part of the river would also influence me somewhat, so that I am not prepared to adopt any general plan, but would prefer to see the whole

question left to a permanent board of engineers, whose business it should be to see that the best interests of the whole country were protected, and no individual caprice suffered to throw obstacles in the way of either river or railway transportation.

I am yours, very respectfully,

FRED. A. CHURCHILL.

G. K. WARREN,
Major Engineers and Brevet Major-General, United States Army.

LETTER OF MR. R. B. MASON, CIVIL ENGINEER.

CHICAGO, *January* 28, 1869.

DEAR SIR: Your circular of December 21, 1868, owing to my absence for the most part of this month, only reached me a few days since.

I was not present, and did not participate in the discussion at the convention of engineers at Saint Louis. I, however, approved generally of their doings; I have never understood from any of those gentlemen that I have talked with since that convention that they considered a 500-feet span impracticable. But a span of 350 feet was considered long enough to meet the requirements of business at that point, and it being cheaper to build with shorter spans, they therefore recommended the shorter spans. This was about the view I took of it. I could not exactly see the necessity of a 500-feet span, and if not necessary, then why build it?

I am not willing to place myself on record that it is impracticable to build a bridge of 500-feet span.

Yours, truly,

R. B. MASON.

G. K. WARREN,
Brevet Major-General.

LETTER OF GENERAL WILLIAM SOOY SMITH, CIVIL ENGINEER.

COUNCIL BLUFFS, IOWA, *February* 8, 1869.

SIR: I have just received your printed circular, dated December 21, 1868, asking how far the convention of engineers assembled to consider the subject of the construction of a railway and highway bridge across the Mississippi River at Saint Louis, intended to decide the question of bridging the great navigable western rivers.

As I have no opportunity to confer with other members of the convention, I can only venture to give you my individual impressions.

I think the spirit with which our inquiries were conducted is very well indicated in one of the sentences quoted in your circular from the opening address of our president, viz:

"Although we have been convened at the request of one of the rival companies, yet we are to consider all of the questions bearing on this subject without reference to any particular plan or company."

And while the facts and opinions were elicited by a single case, they have a legitimate application to all similar ones, and so to the general subject of "Bridging the great navigable western rivers;" though I don't think it was any part of the duty or intention of that convention to extend its inquiries to that general subject.

Perhaps I have now answered all that you intended I should, and yet I cannot refrain from tendering the following considerations upon a subject of so much importance to the engineering profession and to the communities we serve.

I know of but one span (not suspension) that nearly approaches 500 feet in the clear, and that is the long span of the Kuilenburg viaduct, over the river Leck, in Holland, recently completed. This span is 492 feet in the clear, and at American prices for iron and steel would have cost $892,311, three and three-tenths times the cost of the 262½ feet span, and more than the whole 7 spans of 187 feet each of the same viaduct.

The great additional cost of the span proposed (500 feet) will, in my judgment, make the act if passed "practically prohibitory to bridges," except in cases of such necessity as to justify almost any expenditure of money.

I do not think that a 500-feet span is *mechanically impracticable*. The most serious difficulty in the way of the construction and erection of such a span would be experience in shaping and uniting parts of sufficient dimensions to resist the great strains to which they would be subjected, and in providing falsework on a bottom that may be shifting and unreliable; that could not be depended upon for supporting so costly a superstructure during the time necessarily consumed in putting together in place over *two thousand tons* of iron and steel consisting of so many parts.

The steamboat interest demands that bridges over our navigable rivers shall be placed 50 feet in the clear above high-water surface. This requirement greatly increases the difficulty and expense of falsework to sustain a structure so ponderous and

costly. While, therefore, it may be granted that a single span of 500 feet in the clear can be built, it must also be conceded that the construction and erection of such a span over some of the rivers which the public interest requires us to bridge, would demand all the resources of the very best mechanical and engineering talent and experience. *It is to be regarded as an extreme to which the engineer should be driven only by an absolute necessity.*

Moreover, the question of safety involved in the adoption of spans of such great length can scarcely be regarded as settled by *a single example so recently furnished.* Of course it is easier to build a short bridge than a long one, the difficulty increasing nearly in proportion to the squares of the distances to be spanned; and whether the limit of safety, with the plans and materials at hand for the use of the engineer is not reached far within the extreme length of span 500 feet no sufficient experience has yet been had to determine.

The passage of an act making it necessary for the American engineer to exceed with all his bridges over our navigable rivers the greatest length of span yet attained would be viewed with surprise by the engineering profession throughout the world. Legislation requiring us to go beyond the limit of all reliable experience would be unwise, dangerous, and only calculated to prohibit bridges altogether wherever it might apply, except in cases of extreme necessity.

The navigable channels of even our largest western rivers are rarely 500 feet wide—generally not more than half that width. Then why compel engineers and those interested in the vast trade that seeks transit across our rivers to span sand-bars and unnavigable water when such compulsion is so detrimental to these great interests, and involves such nice questions vitally affecting the public safety? Nothing but gross carelessness or criminal intent will bring a steamboat in contact with piers placed from 250 to 350 feet apart in the clear, and parallel with the direction of the current. Otherwise, how can steamboats be kept in the narrow tortuous channels they now navigate?

It so happens that many of our great navigable rivers lie directly across the lines over which our surplus products must move to reach their best markets. This movement is more important in winter than in summer time; but in winter nearly all of our most important western rivers are closed by ice. So that even if they ran in the most desirable directions they would not be available at the most favorable season of the year for the transportation of our products. So it happens that the great bulk of the inland carrying-trade is done by railroads, and the interests of the whole producing population of the West are thus vitally affected by any enactment which will so seriously impede the operations of those roads.

As the trade obstructed by the rivers, increases, the hinderances thrown in its way unnecessarily by the less important river commerce will become more and more objectionable to the people interested. And have they not a right to demand now that while guarding a minor interest a greater one shall not be sacrificed? It is, of course, of first importance that our great natural channels of inland commerce should be preserved. They are free to all, and can never become the property of powerful combinations and monopolies. But they are not seriously obstructed by an occasional bridge with spans of from 250 feet to 350 feet in the clear, and these in their turn serve to perfect other lines of still greater importance to the great mass of our people.

I think the opinion not only of the Saint Louis convention, but of the great body of engineers in this and all other countries, is adverse to 500 feet spans, except in cases of absolute necessity. They are barely practicable. They may or may not prove permanently safe and reliable, and they are enormously expensive.

Yours truly,

WM. SOOY SMITH,
Superintending Engineer, Omaha Bridge.

General G. K. WARREN.

LETTER OF MR. J. B. MOULTON, CIVIL ENGINEER.

NORTH MISSOURI RAILWAY COMPANY,
CHIEF ENGINEER'S OFFICE,
Saint Louis, February 10, 1869.

DEAR SIR: Your printed circular dated at Saint Paul, Minn., addressed to the members of the convention of civil engineers, held in Saint Louis, Mo., in August, 1867, to consider the subject of a railway and highway bridge across the Mississippi River, has been read by me with much interest.

The whole tone of your letter goes to show that your great desire is to collect correct information, to the end of doing the greatest good you can to the railway interests of the West, and at the same time to preserve the integrity of navigation on the Ohio, Mississippi, and Missouri Rivers. These rivers are the great competitors of western railways, as carriers, and the unobstructed, free navigation of which is a matter of great importance to the country.

It is equally important, however, that the railway interest be not overburdened, or be forced to greater outlay of money in building bridges than is necessary to protect the boating interests. Believing that you wished to get the opinions of practical men as well as scientific, I addressed a note to Col. C. Shaler Smith, of the firm of Smith & Latrobe, Baltimore, who combines both these qualities, requesting him to give his views of spans which can be adopted over western navigable rivers without injuring railroad interests too much by great outlays, which I herewith inclose.

I do not fully agree with the views expressed in it as to the necessity of the very long spans mentioned. For while I admit the possibility of constructing long spans, it seems to me that Congress would not be justified in going beyond the requirements of western navigation, and I am one of those who believe that it does not require spans reaching beyond 350 feet. Indeed it seems to me that spans of 300 feet in the clear will accommodate all possible contingencies, except perhaps when made directly opposite our largest cities, where boats of the different classes of tonnage exchange freight. Colonel Smith admits, and in this I agree with him, that the cost of superstructure is nearly as the square of the span; which will make a span of 500 feet cost within 25 per cent. of three times as much as a span of 300 feet. This is more than most western railways can spare to build bridges over the rivers named.

Draw-bridges, built and proposed in some instances, have been and will be built by independent companies, because railroad companies are too poor; these companies charge toll, which nets a profit, and will continue to do so, at the cost of the shipper, no doubt, for a long time.

Owners of railroads will contend that they should not be required to build bridges beyond a span which will not obstruct navigation. Steamboat-owners will contend for long spans, as it is manifestly their interest to keep back the bridges as long as they can, while railroad owners for a parallel reason will contend for the cheapest bridge. A proper discussion will bring the minds of Congress to see the propriety of taking a mean that will do justice to both sides. Pilots will be slow to testify that 300 feet is not enough; a contrary opinion would be refuted by the fact that on every trip at ordinary stages of water they are compelled to steer their boats through channels much less than 300 feet wide, which is often done at night with no moon in sight. It is for the interest of all railroad companies or bridge companies to build high bridges, and they ought to be compelled to do so, as a safeguard against accidents to both bridges and steamboats. Besides, a river carrying almost the whole year an immense amount of sand and silt is likely, and does, in fact, alter its channels, which, with a draw-bridge, will give trouble, while under high bridges it will be avoided.

This will apply with much force to these three rivers, except to the Mississippi above the mouth of the Missouri. Another reason why high bridges should be adopted is that the requisite spans are not attainable with draws.

I am aware that I have not yet answered your question asked in the printed circular, nor is it necessary if what I have said is noticed.

The convention was, as you suppose, called in the interest of the rival bridge company. You mention a fact I did not happen to know when I accepted the call to attend, and many of the civil engineers whose names are appended to the report did not attend, although I think they all saw the report and signed it before the printed form had much circulation. I did not have much to do in the matter, except to contribute to the "Report on the regimen of the river near Saint Louis and Saint Charles." The gentlemen composing that convention with whom I became acquainted, many of them for the first time, while in Saint Louis, are engineers much older and better skilled in bridge-building than I am, and to whose opinions I defer. My opinions as to spans best adapted to bridges on the Ohio, Mississippi, and Missouri rivers are contained in this communication.

Under different circumstances I should have much preferred to have been silent; as it is I write with a full knowledge of the inadequacy of my experience and judgment in treating a subject properly, so vital to the commercial industry of the West.

Your obedient servant,

J. B. MOULTON.

General G. K. WARREN, *U. S. A.*

LETTER OF GENERAL C. SHALER SMITH, CIVIL ENGINEER.

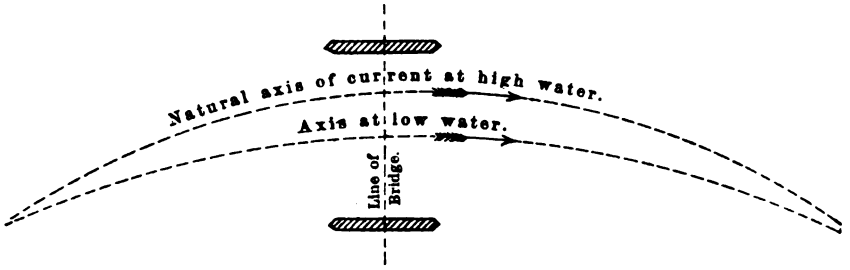
NORTH MISSOURI RAILWAY,
ENGINEER'S OFFICE, SAINT CHARLES BRIDGE,
Saint Charles, Mo., January 23, 1869.

DEAR COLONEL: In reference to the letter of General Warren received from you, I would say that in regard to the proper length of spans on navigable streams, I have come to the following conclusions:

First. That the location should be such that there is a clear distance both above and below the bridge, of two and a half boat lengths (longest boat in the trade) of straight

current, and that where this is the case the span should be sufficient to allow the longest boat on the river to float through sidewise, and the longest and broadest tow-fleet to go through at an angle of 30° with the line of the current. The location of the piers, in this case, should be such that the *natural axis* of the current is through the middle of the span, without reference to the deepest water. Where this is attended to, the normal action of the current will carry an unmanageable boat or tow through without danger.

Where the location cannot be made over a straight current, the principles which should govern are these: Ascertain the distance in the line of the bridge between the axis of the current at the lowest navigable stage, and the same at the highest water, and *add this distance* to the lengths of span previously determined for a straight current. This will carry a boat through as before, by the natural action of the current alone, whether the river be low or high. You can judge of the principle from the following sketch.



I have made a good many experiments on the lee-way made by boats in turning a bend and from wind, but I find the foregoing principles come more near to covering all possible points than any plan I have yet seen or thought of. In applying this to practice on the Missouri River, we have, at the Saint Charles bridge, 1,000 feet of straight current above the bridge and 1,800 feet below. From the regimen and character of the river, tow-boats will never become profitable on it; so the longest boat fixes the span; this is 285 feet, and allowing 15 feet at each end of the boat for clearance, we have 315 feet as the proper span.

The arrangements here suit the river interests so well that not only have they not attempted to enjoin us, but a number of pilots have voluntarily communicated with me for the purpose of expressing their entire satisfaction.

On the Mississippi and Ohio Rivers the longest tow-fleet would fix the spans. This would be 7 barges wide and 3 barges long, or a rectangle of 480 by 182 feet. This, at an angle of 30°, will require 400 feet net, and 430 feet with the proper clearances. This for a span over a straight current. In the curved current in the bend just at Saint Charles, where the varying axis of the current equals, I should think, the variations likely to take place at any point on the Ohio or Mississippi Rivers which would be selected for a bridge, the distance between the high and low water axis is 80 feet; add this to 430 feet, and we have 510 feet as the widest span which would probably be required on the rivers in question.

In relation to the practicability of these long spans, this is simply a matter of cost. Any one of the four or five of the best forms of truss in use in this country can be extended to 700 feet span in iron or 1,000 feet in steel, without either difficulty or danger. One of our firm has just successfully extended the common Howe truss, without an arch but with a wrought-iron lower chord, to 300 feet span, and this without exposing the wood at any point to more than 1,000 pounds per square inch, with the truss fully loaded. When this can be done with a material like wood, it is easy to see the extended limit which can be reached with such a material as steel, which is good for 25,000 pounds per inch.

Up to within the limits I have given, the cost of a truss is very nearly in proportion to the square of the span, the girders of the arch and bowstring types, however, increasing in relative economy with the truss-girders proper, as the spans are lengthened.

Yours, very truly,

C. SHALER SMITH,
Chief Engineer Saint Charles Bridge.

Col. J. B. MOULTON,
Chief Engineer North Missouri Railroad.

[Indorsement.]

Respectfully referred to General G. K. Warren, U. S. A.

LETTER OF MR. W. W. EVANS, CIVIL ENGINEER.

NEW YORK,
47 *Exchange Place, February* 15, 1869.

GENERAL: I am in receipt of your circular letter in reference to the report of the convention held in Saint Louis in August, 1867, to consider the subject of a railway and highway bridge across the Mississippi River at Saint Louis.

In answer I would say that, although my name appears as one of the convention, I was not present, and did not see the report until after it appeared in pamphlet form.

The president of that convention was my chief for a number of years, and having always had the most exalted opinion of his engineering ability, I told him I would sign the report, and would sign anything he would put his name to. In this way, my name became attached to the report.

I beg now to say, in reference to the questions asked, that I fully believe in the practicability of building girder-bridges of 500 feet clear span, but I do not believe in the propriety of them in any case or under any circumstances, but I do believe in the propriety, the economy, the reliability, and the usefulness of bridges of suspension for railway and highway purposes of spans ranging from 500 to 3,000 feet.

Why the law should have been framed to exclude the suspension principle is, to me, inexplicable, when we have in existence a railway-bridge of much greater span which has given satisfaction.

That bridges on the girder principle of 500 feet span can be built there is now no longer reason to doubt, with the knowledge we have of the Britannia bridge, 459 feet 3 inches span, and the bridge just constructed over the Leck at Kuilenburg, in Holland, of 492 feet span, and another over the Moldau at Prague, in Austria, of the same span. But I would ask, what engineer is there in the United States bold enough to recommend such bridges for construction here, when he has staring him in the face the figures 2,123 as the tons of iron and steel used in the construction of one span of 492 feet, and the figures 3,000 as representing the tons of iron used in one span of the Britannia bridge, of less than 460 feet, and then compare these figures with the 400 tons of iron and less than 600 tons of wood used by Roebling in the construction of the Niagara Suspension bridge, of over 800 feet span. I am fully convinced, after years of investigation, that bridges of 500 feet span of iron and steel for railway purposes, having no curved lines in any of the chief members, and having as much rigidity as the Britannia bridge, can be built, and successfully built, on the truss suspension principle with much less than 700 tons of metal. Fink's patent suspension truss-bridge, as now built by an eminent engineering firm of Baltimore, and very extensively used throughout the country in spans of 250 to 400 feet, combines many of the features required in a Roebling bridge. This plan may, in my opinion, be improved for very long spans, by introducing a plan for keeping the main suspension members in straight lines, by auxiliary chains, as supporters of the sag, which would naturally take place. This feature in bridge-building will, before long, be understood, appreciated, and used for railway bridges, of very long spans. I see no good reason why railway bridges of 1,000, 1,500, or even 3,000 feet span should not be built, when occasion and circumstances call for them. But spans of these dimensions evidently cannot be built where the chief members are arches, depending on compression for strength. Bars, or beams, or columns, beyond a certain length, cannot be depended on for strength, without much lateral bracing and propping on every side, and even then no man can tell when and where buckling and doubling up will take place, while a bar or chain of iron or steel, or cable wire, has a known strength, no matter what the length, and can be relied upon.

The suspension principle is fully understood and appreciated by the leading engineers of the United States; so it is a folly for legislators and others, at the present day, to ignore its merits.

Mr. Roebling deserves much praise and lasting honors for the boldness exhibited in design and the skill developed in execution, in railway bridges of suspension, and that, too, after the matter had been discussed and condemned by the Institution of Engineers in England.

It is shown by actual results that the deflection of the Niagara suspension-bridge, which has a span of 821 feet 4 inches, is about the same in proportion to the span as that of the Britannia bridge, a rigid iron-plate girder, of 459 feet 3 inches, while each are loaded with 300 tons.

When the Niagara suspension railway-bridge became a fixed fact, European engineers made it the subject of much discussion. Many of the routine engineers, those that had been brought up in a groove, could not believe in it, and do not believe in it to this day; but one among them, a well-known writer on the strength of materials, Peter W. Barlow, packed his valise, came to this country on purpose to look at this wonder after it had been in existence over five and a half years. It may be interesting to quote some of his opinions and conclusions, taken from a pamphlet published on his return to England. On page 6 he says: "The suspension principle, if correctly

carried out, is the safest as well as the most economical application of iron to railway structures." On page 18: "Oxidation is slow where every point can be got at and painted. Tube-bridges, with cells difficult to be got at, will be more liable to loss of strength from this cause." Page 19: "The durability of the Niagara bridge cables will not be less than the masonry of which the towers are built." Page 22: He shows the ratio of strength to strain by weight of bridge to be, in the Niagara bridge, 6.5 to 1, and in the Britannia bridge, 3.4 to 1; the Conway bridge, 3.8 to 1, and the Saltash bridge, 5 to 1. Page 30, he says: "The Niagara bridge is the safest and most durable bridge of large span that has been constructed. Had wrought iron been used for trussing, the total weight would not have exceeded 800 tons, the deflection of the wave reduced to 2 inches, and the strain on the cables to one-eighth of their ultimate strength. It is clear, therefore, that 820 feet is not the limit of the opening that can be crossed by this principle, but that spans as high as 3,000 or 5,000 feet can be carried out for railways without exceeding the safe limit of strain on the wire cables, and at a cost which would render remunerative connections and communications which are now considered impracticable." Mr. Barlow then goes on to estimate the dimensions, strength, and cost of a suspension bridge of 3,000 feet span which he proposed to build between Liverpool and Birkenhead.

From the foregoing notes and opinions of one of the first of English engineers, together with what we know and can see for ourselves, who is there that can doubt; who is there bold enough to ignore the strength, the economy, the safety, the durability, and the good merit of the suspension principle for railway-bridges of great span? I am in the belief that a very large portion of the educated people of this country are ignorant of what can be done with steel, and how differently it will act under certain circumstances of extension and compression. It is common among engineers to demonstrate facts and show differences by caricatures. Let us take this method to show what steel can do in tension, and what it *cannot* do in compression. Suppose steel wire to have a tensile strength of more than 150,000 pounds to the square inch; also, that 1-inch cube will have a compressive strength of more than 150,000 pounds, and there is plenty of steel that can be found that will exceed these figures. Now, let us suppose that 4 cubic inches will weigh one pound, which, in round numbers, is not far from the truth, there will be 50,000 feet of solid steel wire (one square inch area) in the 150,000 pounds, and there will be tensile strength enough in it, if in one piece, to hold itself, if suspended from a point 50 000 feet above the earth, and hanging in a straight line. Then suppose you rest the lower end on a well-prepared foundation, and let go of the upper end, what would become of the 50,000 feet when you come to depend on its compressive strength? Is it not clear that it will double up into a thousand folds and twists, and come down to mother earth with a rush? and yet the first cubic inch at the bottom was prepared to hold the whole of it without crushing. Suppose we take 3,000 feet of this 1-inch square solid cable of steel wire and hang it on a hook 3,000 feet above the earth, what will it hold? Why, it will hold itself, which will weigh 9,000 pounds, and a ball of 141,000 pounds, which is the balance of 150,000. But what will become of the 3,000 feet if compression is depended on, to say nothing of the 141,000-pound ball? Why, it will come down as before. What will become of 10 feet of this cable, of 5, or even 2 feet of it, if it is stood up, and the 141,000-pound ball, or the tenth part of it, was placed on top? Why, it would buckle, and the ball would have a tumble.

This, general, is not a very scientific way of writing, but it is one every person can understand, and I only write it in this caricatured light to show the difference that exists between compression and tension in long-span bridges, where economy and reliability are considered, and where the engineer is performing his chief function of making the most out of the least.

Captain Eads is a bold man to design an arched bridge with spans of 500 feet, and will deserve credit for his boldness and nerve if successful, but I doubt if he will deserve or receive much credit for spending two or three times the amount the circumstances called for.

I remain, general, your obedient servant,

W. W. EVANS.

ANNUAL REPORT OF CAPTAIN EADS FOR 1869.*

The next report of Captain Eads, chief engineer, made to the president and directors, that I have seen is dated September 1, 1869. It is contained in nineteen pages, 8vo. He had visited Europe in the preceding winter, and witnessed the *plenum pneumatic* process of sinking piers, which he thought so favorably of that he proposed to adopt it in

* Illinois and St. Louis Bridge Company. | Report | of the | Chief Engineer, | September, 1869. | St. Louis, | Missouri Democrat book and job printing house, | 1869. |

sinking those of this bridge to the bed-rock. Much work of preparation had already been done, but the masonry building had been confined to the Saint Louis abutment and the piers of that approach. Mr. W. Milnor Roberts had been appointed associate chief engineer.

ANNUAL REPORT OF CAPTAIN EADS FOR 1870.*

This report occupies, with an appendix, 55 pages 8vo, and is accompanied by a drawing showing the bridge-spans as revised, and the rock stratum on which the piers were to rest. There are besides four plates showing construction works and machinery, caissons, arrangements of air-locks, &c. The final designs were now essentially completed, and the work well under way. The account of the methods employed and the experience developed make it a very interesting and valuable report. The final design for the ribbed arches makes the steel tubes 18 inches in diameter, placed 12 feet apart from centers and connected by triangular bracing. There are four such in each span, and the arc is the arc of a circle. The versed sine of the center span is 47.5 feet and the crown is 55 feet above the city directrix, so that the springing line is 7½ feet above the city directrix. The springing line of the side spans next the abutments are 18 inches lower, or 6 feet above the city directrix. The highest known flood, that of 1844, was 7.58 feet above the city directrix, so that it is barely possible that the extreme floods can reach the arches at the springing lines. The versed sine of the side arches is 43 feet, so that the crowns are 50.5 feet above the city directrix.

The great objection made to this form of structure by the navigation interests is in its allowing so little width of full headway. The report of 1870 is the last one I have seen from the engineer of the bridge.

REPORTS OF A BOARD OF ARMY ENGINEERS.

When in the summer of 1873 the near approach of the completion of the arches of the span next to Saint Louis brought to the steamboatmen's eyes the exact nature of the effect the bridge would have upon navigation, the steamboatmen at Saint Louis became much disturbed and made application to the Secretary of War to have the nature of the impending obstruction investigated and reported upon by a board of engineers. This board, of which General J. H. Simpson was president, was convened by special orders dated August 20, 1873, which directed an examination to be made, and report whether the bridge will prove a serious obstruction to the navigation of the river, and, if so, in what manner its construction can be modified.

The board reported, September 11, that it would be a serious obstruction, and could devise no remedy, if the bridge was allowed to stand, except to build a canal around it on the Illinois side and place a drawbridge over the canal. This report was replied to by Captain Eads, and charges of unfair treatment were made by the bridge company's agents. A replication was made by the board in a supplemental report dated January 31, 1874. The whole was printed as House Ex. Doc. No. 194, Forty-third Congress, first session, comprising 45 pages 8vo. It was reprinted in the Annual Report of the Chief of Engineers for 1874, pp. 636–680, and contains a good deal of useful information. I will caution any one from being misled by the last three horizontal rows

* Illinois and St. Louis Bridge Company. | Report | of the | Chief Engineer, | October, 1870. | St. Louis, | George Knapp & Co., printers and binders, | 1870. |

of figures in Table H. The last two should be stricken out. The result will be properly stated in Chapter III of the present report.

The bridge was completed and opened for travel in July, 1874.

OTHER SOURCES OF INFORMATION CONCERNING THE SAINT LOUIS BRIDGE.

The Transactions of the American Society of Civil Engineers contains several papers:

(1.) In volume II, pp. 135–139, paper No. XLVII, is: "A description of the proposed plan for erecting the superstructure of the Illinois and Saint Louis bridge," accompanied by an illustration by Walter Katté, C. E., read June 6, 1872.

(2.) In volume III, pp. 195–215, paper No. XCVIII, with six plates of illustrations, "UPRIGHT ARCHED BRIDGES," by James B. Eads, civil engineer, read June 10, 1874.

This paper presented a different form of bridge from that at Saint Louis, to remedy some of the disadvantages of the system adopted for the superstructure of that bridge. He aimed "to show that upright arched bridges can be more economically constructed than is possible by any other method whatever, no matter what length of span may be required." This proposition was contested in a discussion which followed the reading by C. Macdonald, p. 215; A. Welch, J. D. Steele, and W. S. Pope, p. 216; T. C. Clarke, p. 222; L. Nickerson, p. 224; S. H. Shreve, pp. 227–232; S. Whipple, pp. 235–238.

Mr. Shreve continued the discussion, volume III, pp. 285–286, and submitted a "comparative estimate of the amount of iron in the trapezoidal truss and in the upright arch, reduced to like conditions." Mr. Clemens Herschell submitted additional remarks on the subject of upright arched bridges, pp. 286–288. Mr. Eads replied to the criticisms made, pp. 319–334.

(3.) In volume III, pp. 239–254, paper XCIX. *Notes* on the erection of the Illinois and Saint Louis bridge, presented June 10, 1874, by Theodore Cooper, with sketches to illustrate. This paper contains some accurate information about the joining of the parts of the steel tubes not given elsewhere.

(4.) In volume IV, *Upright bridges discussed.* S. Whipple, pp. 81–85; S. H. Shreve, pp. 162–173; James B. Eads, pp. 174–184; S. Whipple, pp. 201–203.

ROEBLING'S DESIGNS FOR BRIDGES AT SAINT LOUIS.

Detailed plans for three different bridges at this place were elaborated by Mr. John A. Roebling, civil engineer. They were to accommodate two railway-tracks on one floor, and a wagon-way for vehicles and street-cars to pass both ways, and with two sidewalks above. The headway to be allowed steamboats was 90 feet above low water, or about 57 feet above the city directrix. Two of the designs were for a parabolic truss, and one for a pure suspension bridge. The work also contains complete designs for a parabolic truss-bridge for the Ohio River with one span of 500 feet and two adjoining ones of 300 feet; also plans for various spans 400 feet and less.

The designs were completely worked out, and were about finished for publication when he met with the accident while surveying the site of the East River bridge, which caused his death. The work was afterward published and elaborately illustrated by his heirs, forming a folio

of 48 pages, including a preface by his son, Washington A. Roebling, civil engineer. Short-span bridges occupy two additional pages, and there are some 20 pages of tabular statements of strains, costs of steel trusses, &c. There are 13 beautifully-executed steel plates giving general and detailed forms and dimensions of parts. The frontispiece is an excellent likeness of this renowned engineer. The work is published by D. Van Nostrand, 23 Murray street, and 27 Warren street, New York, 1869. The title-page is, "Long and Short Span Railway Bridges, by John A. Roebling, Civil Engineer."

"The greatest economy in bridging can only be obtained by a judicious application of the parabolic truss."

RECENT DECISIONS OF THE UNITED STATES SUPREME COURT FOR DAMAGES SUSTAINED AT THE SAINT PAUL RAILWAY DRAW-BRIDGE.

The following decisions in the cases of the *Lady Pike* and the *Mollie Mohler* have much interest. This bridge is just at the upper limit of the field of investigation assigned to me. The bridge, as far as I know, has never been declared a post-route by Congress. It is authorized by the legislature of the State of Minnesota, in which both banks of the river are situated, and is all within the jurisdiction of one United States district court; so that it seems probable that the owners of the steamboats could have brought suits for damages against the bridge-owners, but I am not aware that they ever did. The great danger the piers of the bridge occasioned to navigation is so fully set forth by the Supreme Court, that it seems hardly possible that any one would have been allowed to so obstruct a navigable stream. There was nothing left the navigator but to stop or to undertake risks for which he had to pay all the damages. The case of the *Lady Pike* was decided at the October term in 1874 (Wallace Reports, vol. 21, pp. 1 to 17), from which the following is extracted:

Appeal from the circuit court for the eastern district of Wisconsin.

The Germania Insurance Company had insured a cargo of wheat laden on a barge at Shakopee on the Minnesota River, and about to be towed by the steamer Lady Pike down the river to its junction with the Mississippi, thence down the Mississippi to Savannah, Ill., *unavoidable dangers of the river* * * * only excepted. The cargo was laden on the barge, and the transportation of it begun. In the course of the voyage, however, the barge was wrecked. The insurance company paid the loss, and, alleging that the barge had been wrecked owing to the negligent manner in which the steamer had towed her, filed a libel against the steamer to recover what had been paid for the loss. The owners of the steamer set up that the wrecking had been caused by an "unavoidable danger of the river," and was therefore within the dangers from which they had excepted themselves. And whether the catastrophe was caused by an "unavoidable danger of the river" or by the steamer's negligence was the question.

The case was thus:

In April, 1866, there stood in the Mississippi River, just above Saint Paul, certain piers of a bridge then in process of construction, beginning on the west side* of the river, and numbered 1, 2, 3, 4, and 5, pier No. 3 (a turn-table pier) being so far unfinished as that, *when the river was high*, barges like that on which this wheat was laden could pass in safety over it, though when the water was low they could not. In low water the pier was exposed. Owing to a gravel-point on the west side of the river, which projected itself into the stream, and against which the water struck, the current, in high water especially, rebounded and ran diagonally across the piers, toward the east shore, so that "a boat in going between piers No. 3 and No. 4 would drift from 4 to 6 feet towards pier No. 4."† Hills bounded each side of the river for many miles

* "West or right bank" is here more properly the *southeast* side, as the river flows in this part northeast.—G. K. W.

† The United States laws authorizing bridges require that the piers shall be parallel to the current of the river. These bridge-piers would not have been in accordance with those laws.

along its course, with occasional openings or "coolies,"* as the navigators call them, through which wind blows, that at other places in the river are arrested by the hills. One of the openings or coolies existed on the west side of the river, opposite to these piers. The space between piers No. 3 and No. 4, when No. 3 was above water, was about 116 feet; that between No. 2 and No. 4† was 264 feet; that between No. 4 and No. 5 was 151 feet. The main part of the channel was between No. 3 and No. 4; there was the draw of the bridge, and it was between those piers that boats and tows going down the river, and sufficiently narrow to pass through in safety, usually went. The passage between No. 4 and No. 5 was, at one time, obstructed by a sunken barge, but this was after the time of the transit now under consideration. That passage—the passage between No. 4 and No. 5—at this time was clear and of sufficient depth for the *Lady Pike* and her tow to have passed in safety.

In this state of things it was, the rivers Minnesota and Mississippi being at the time full with spring waters, that the Lady Pike, a stern-wheel steamer, "a high boat which would catch a good deal of wind on her sides," set off from her moorings with three barges in tow, laden with 600 tons of wheat, a tow which was to be styled a heavy tow. One barge, larger than the other two, was lashed on one side, and the remaining two upon the other.

The width of all the vessels, steamer and barges, when close alongside each other, was 105 feet. They were all stanch and the steamer abundantly supplied with men, including two master mariners and two pilots. Scudding clouds prevented the day from being absolutely clear, and "puffs, gusts, or squalls of wind" came up from time to time. These had "bothered" the pilot nowhere, however, in a way worth mentioning, and the vessel had had no trouble except a little in going between the piers of another bridge higher up the stream, between which, however, they had got safely.

On approaching the piers just above Saint Paul, of which we are now principally speaking, the vessel being under a headway of about 7 miles an hour‡—no squalls *then* blowing and no "slow bell" having been sounded, the pilot of the steamer, judging by his eye, and thus judging, being under the impression that he could do so safely, attempted to run his steamer and its tow between pier No. 3 and No. 4. He was apparently ignorant of the exact width of his steamer and its tow, ignorant also of the exact distance between the piers, and ignorant, besides, of the fact that in the then height of the water he could have run *over* pier No. 3, and ignorant in addition, or not appreciative of the diagonal effect of the current as it set in high water between the piers. The result was that one of the barges struck pier No. 4 and was wrecked.

The captain and other officers of the steamer swore that *just as they were going through the piers* a squall arose and drove the barge against the pier; that the accident arose through no negligence, and was an unavoidable danger of the river.

The district court held that this was the true view of the case, and dismissed the libel.

The circuit court affirmed the decree, and the case was now brought here by the insurance company for review.

Arguments on both sides were made, and Mr. Justice Clifford delivered the opinion of the court, from which the following extracts are made, relating especially to the navigation and the bridge:

* * * * * * *

They, the steamer and barges, were all arranged abreast, the larger barge being lashed to the starboard side of the steamer, and the smaller of the other two being lashed to the port side of the steamer between the steamer and the starboard side of the barge containing the wheat which is the subject of litigation. Different estimates are made by witnesses as to the width of the whole craft as arranged, but the evidence taken as a whole, convinces the court that the steamer and the three barges combined, including the guards of the steamer and the planking of the barges, could not have been less than 105 feet, even if they were all closely lashed together, which is highly improbable. Lashed as they were, broadside to broadside, of course the stem of the steamer was much in advance of some or all of the respective stems of the barges, as she exceeded in length even the largest barge more than 50 feet §

* Properly *coulé*, a name given by the Canadians to the ravine made by a side rivulet or run.

† When No. 3 was below the water.

‡ This speed must have included the velocity of the current.—G. K. W.

§ It is highly improbable that the tow was made up in the position, with regard to the bows of the steamer and barges, which the court inferred. The practice with navigation is to make the barges project in front of the steamer, so as to facilitate steerage and control over them. It would be proof of the captain's incompetency if he neglected this advantageous custom and took the arrangement accepted by the court.—G. K. W.

The opinion of the court continues to narrrate the proceedings of the case, stating that the decision of the district court was against the libellants of the boat, and that the circuit court had entered a decree affirming it.

Whereupon the libelants appealed to this court.

Errors assigned here are in substance and effect as follows:

1. That the steamer and barge were not properly manned, nor were they fit for the voyage, as neither the master nor pilots had either the requisite knowledge of the vessel under their command or of the dangers and difficulties of the navigation which they had to meet in the course of the trip down the river.

2. That the pilot improperly endeavored to steer the craft midway between piers Nos. 3 and 4, when he ought to have known that the latter pier was so far under water that the craft might have safely passed over it, as was usually done in times of high water, by which improper and unnecessry act the barge containing the wheat was brought within 5½ or 6 feet of the pier which she struck; whereas, if the pilot had steered the craft farther to the westward and passed over that pier, as he should have done at that stage of the water, the distance to the piers on either side of the craft would have been so great as to have avoided all danger of collision.

3. That the craft might have been navigated in safety between piers Nos. 4 and 5, which are 151 feet apart, showing that the craft might have been navigated through that pass leaving a space on either side of 23 feet, which is manifestly too great to have been overcome by the alleged gust of wind.

4. That the speed of the steamer with the barges in tow in passing between the piers was improper and unwarrantable, and was the efficient cause of the disaster and loss.

5. That it was the course of the current which was unknown to the pilot that drove the craft to the leeward, and not the wind, as alleged in the answer, and the libellants allege that the pilot, if he had had proper knowledge of the navigation, might have prevented that movement of the craft by the exercise of due skill in steering.

1. Applied exclusively to the number of the steamer's company, the complaint contained in the first assignment of errors would not be well founded, as the crew was sufficient in number, and the proofs show that the steamer had on board two pilots and two master mariners, but the gravamen of the complaint is that neither the master in charge of the deck nor the pilot had any sufficient knowledge of the craft under their command, nor of the dangers of the navigation in passing down the river in such a steamer with three such barges in tow arranged in the manner before described.

Proof of the most satisfactory character is exhibited that they (the master and pilot) did not even know the width of the craft, as the same was arranged, nor the actual distance between the piers where the disaster occurred. On the contrary, it appears that they both overestimated the width of the space between the piers, and underestimated the width of the tow, including the steamer, as they were arranged abreast, the distance between the two first-named piers not exceeding 116 feet, and the width of the whole craft being at least 105 feet. Nor does the fact that the pier on the starboard side was so far under water that the craft might have passed over it palliate the rashness of the act, as the evidence shows that both the master and the pilot were ignorant of the fact, and, as they approach the place of danger they put the steamer upon a course to cause the whole craft to pass midway between those two piers, which brought the port side of the barge containing the wheat within 5 or 6 feet of the pier on that side, which was not submerged in the water.

2. Attempt is made to excuse the master and pilot for endeavoring to pass midway between those piers upon the ground that it would be safe to pass over the pier on the starboard side, but the sufficiency of that excuse cannot be admitted for two reasons: (1) because they ought to have known both the dangers and the facilities of navigation before undertaking the responsible duties in which they were engaged; (2) because it was their duty, if they believed that the pass in question was restricted to the distance between the two piers, to have taken the other pass, which the evidence shows has the width of 151 feet.*

Opposed to that is the suggestion that the wider passage was obstructed by a sunken barge, but the evidence satisfies the court that the alleged obstruction did not exist at that time, and that the disaster that caused that barge to sink occurred at a later period.

3. Unobstructed as the wider passage was, it was plainly a rash act to attempt to pass down the narrower passage on a course which brought the port side of the barge containing the wheat within 5½ or 6 feet of the pier on that side, which act can only be accounted for upon the ground of negligence and inexcusable ignorance of the dangers and facilities

* It must be borne in mind that none of the spans of the bridge were yet put up. If they had been, then the passage run by the *Lady Pike* would have been the only available one, and not the opening of 151 feet not yet spanned.—G. K. W.

of the navigation, as it was evidently a hazardous experiment to attempt to pass between those piers if the craft could not pass over the pier on the starboard side, and it is equally clear that it would have been safe to have steered between the piers forming the wider passage, which it seems never occurred to the master or pilot.

4. Even if such an attempt could be justified at all on a windy day when the water was high, it is quite clear that neither skill nor good judgment was exercised in setting the course of the craft before passing between the piers.

Beyond all doubt some allowance, though the margin was small, should have been made for the leeway of the craft, as the evidence is convincing that the course of the current at high water tends somewhat to force the craft toward the pier on the port side. Besides, they had met with some difficulty previously during the trip that day at the bridge higher up the river, and therefore were forewarned that a like difficulty might again occur.

Ignorance of the danger before them is no sufficient excuse, as the owner appoints the master and is bound to select one of competent skill and knowledge to transport goods and merchandise shipped on board in safety, which necessarily imposes the obligation to employ a master-mariner who knows enough about the route to avoid the known obstructions and to choose the most feasible track for his route. Knowledge of the kind in river navigation is peculiarly essential, as the current frequently shifts from one side towards the other, and the track of navigation is often obstructed by snags, sand-bars, and shoals, which no degree of skill would enable the mariner or pilot to avoid without a prior knowledge of their existence.

Cross-currents between the piers of the bridges, which span the river somewhat diagonally, are not infrequent, and as they are not always fully appreciable to the casual observer it is important that the master-mariners should know of their existence and something of their force in order that they may be able to steer their steamer or other vessel properly through such a passage. Neither the master nor pilot in this case knew that there was any such cross-current between these piers, and consequently took no precaution to guard against its influence.

Carriers of merchandise by water seeking general employment are to be regarded as common carriers, and like common carriers by land, in the absence of any legislative provision prescribing a different rule, are in general to be held responsible as insurers, and consequently are liable in all events and for every loss or damage to the merchandise, unless it happened by the act of God, the public enemy, or by the act of the shipper, or by some other cause or accident, without any fault or negligence on their part, as expressly excepted in the bill of lading or contract of shipment.

Standard authorities show that the first duty of the carrier, and one that is *implied by law*, is to provide a seaworthy vessel, well furnished with proper motive power and furniture necessary for the voyage. Necessary equipment is as requisite as that the hull of the vessel should be stanch and strong, and she must also be provided with a crew adequate in number and competent for their duty with reference to all the exigencies of the intended route, and with a competent and skillful master of sound judgment and discretion and with sufficient knowledge of the route and experience in navigation to be able to perform in a proper manner all the ordinary duties required of him as master of the vessel.

Owners of vessels employed as such carriers must see to it that the master is qualified for his situation, as they are responsible for his want of skill and knowledge in that behalf, and for his negligence and bad seamanship. In the absence of any special agreement to the contrary, or exception in the bill of lading or contract of shipment, his duty extends to all that relates to the loading, as well as the safe-keeping, due transportation and right delivery of the goods, and for the faithful performance of all those duties the ship is liable as well as the master and owners.

5. Differences of opinion may arise as to the merits of the fourth assignment of errors, and inasmuch as enough is alleged in those which precede and follow it to show that the decree of the circuit court must be reversed, the court here does not find it necessary to determine the question whether the speed of the steamer, in view of the conflicting testimony upon the subject, was or was not greater than the exigencies of the impending peril would justify.

6. Nor is it necessary to express any decided opinion whether the fifth assignment of error is or is not supported by the evidence exhibited in the case, but it is deemed proper to say that there is much reason to conclude that it was the course of the current that forced the craft to the leeward and not the gust of wind, as was supposed by those in charge of the deck of the steamer at the time the barge was sunk. Enough appears to show that the bridge there does not span the river directly across the current and that the tendency of the current is to force the vessel passing down the river to the leeward; and the evidence is full to the point that neither the master nor the pilot had any knowledge that they would have to encounter any such difficulty in attempting to effect the passage between those piers Support to that proposition is found in the fact that they did not think it necessary to adopt any precaution to prevent such a disaster, except to see that the craft headed midway between the piers of the narrow

passage and to give the steamer a full head of steam, so as to make the passage as quick as possible, which shows beyond all doubt that little or no use could be made of the helm during the passage, except to steady the craft on the course adopted just before they entered the passage between the piers where the disaster occurred.

Reliable means to ascertain with certainty what force it was which caused the craft to make leeway during the passage is not exhibited in the record, nor is it necessary to decide that point as it was plainly a rash act to undertake to steer the craft through that passage on a windy day when the banks of the river were full, in the face of the dangers which the evidence satisfies the court would necessarily be encountered in such an attempt. Neither the state of the water nor of the wind was such as to furnish any just excuse for the master or pilot, as they might have chosen the other passage, or have taken proper and seasonable measures to leave back one of the barges for the next trip.

Ship-owners are responsible for such a disaster if it results from the ignorance, unskillfulness, or negligence of the master or those in charge of the vessel. Where the master, being ignorant of the coast, sailed past the port to which he was destined and ran into another port in the possession of the enemy and was captured, the court of King's Bench unanimously decided that the implied warranty to provide a master of competent skill was broken by sending out one who was unable to distinguish between the two ports.

Ignorance and unskillfulness being proved, the attempt to set up inevitable accident is vain, as such a defense can never be sustained, even in a collision case, unless it appears that neither party was in fault. Loss or damage occasioned by such a disaster, where it appears that those in charge of the deck were incompetent to perform the required duty either from inexperience, or want of knowledge of the route, or from negligence or inattention, cannot be regarded as being the result of natural causes, nor as falling within the exception contained in the bill of lading or contract of shipment.

Different definitions are given of what is called inevitable accident, on account of the different circumstances attending the disaster, but there is no decided case which will support such a defense where it appears that the disaster was occasiond by incompetency, unskillfulness, or negligence of the master or pilot in charge of the deck.

Service was not made in this case upon the barge, and, of course, the decree must be founded upon the fault of the steamer and those who were responsible for the unskillfulness and bad judgment exercised in her navigation.

Decree reversed with costs, and the case remanded with directions to enter a decree for the libelants and for further proceedings in conformity TO THE OPINION OF THE COURT.

The case of the *Mollie Mohler* is also reported in Wallace, vol. 21.

Appeal in admiralty from a decree of the circuit court for the eastern district of Wisconsin.

The Home Insurance Company of New York was the insurer of a cargo of wheat shipped on a barge appurtenant to the steamer Mohler, on the 12th of May, 1866, at Mankato, on the Minnesota River, in the State of Minnesota—the river then being high—and destined to Saint Paul on the Mississippi. The bill of lading contained the usual exception of "the dangers of navigation." The barge was wrecked by collision with one of the piers of a bridge just above the city of Saint Paul, at about eight o'clock on the evening of the day on which the voyage began, and was totally lost.

The insurance company paid the loss and filed its libel in the district court to recover the amount under its right of subrogation.

The answer set up that the accident occurred through a sudden and unexpected gust of wind which overtook the boat as she was about passing through the piers, and that she was therefore not answerable for the consequences of the collision.

The case was heard on the testimony introduced by the respondents, the libelants having called no witness.

The weather in the morning of the day when the boat set off was calm, but during the afternoon became rough and windy, so much so that the boat laid up at Mendota, near the mouth of the Minnesota River, and about 4 miles above the piers, on account of the wind.

After sundown—that is to say, a few minutes after seven o'clock—she proceeded on her voyage, the wind having "abated," as the master said, or, according to the testimony of the mate, having "calmed down some." At eight the barge struck the pier, killing a man on board and sinking the barge. The night was starlight, and the piers had signal-lights upon them.

On the trial there was great discrepancy between the testimony of the master and that of the mate as to the condition of the wind after the boat left Mendota. The master swore that there was no wind to affect the boat until the *Julia*, an ascending boat, got near the *Mohler*, while the mate said that the wind rose after the *Mohler* left Mendota, and blew hard by spells all the way down. They also disagreed as to the point where the *Julia* was met, the master saying that it was not more than a quarter of a mile above the piers, while the mate fixed the distance at 1½ miles.

From Mendota down to within a short distance of these piers, high bluffs, it should be stated, line the sides of the river, and prevent boats feeling or being affected by the wind, but that just before reaching the piers the bluffs recede from the river and open so as not to operate as a protection from the wind; and that on reaching this point wind will be felt, and sometimes very strongly, though before arriving at this point it would not be. On coming near to these parts there was no doubt that the wind had not gone down, and that it was from a dangerous quarter, the south, the river here running east and a south wind tending to drive a boat on a pier.

When we came within about half a mile of the piers [said the pilot], gusts came at times hard enough to split the posts of fences, but they lulled. Then a heavy gale struck us four or five lengths above the piers. We could not have then changed our course or made a landing. Everything possible to prevent a collision was done; but the collision was inevitable.

An expert witness—of the respondents of course—on cross-examination, testified that within a quarter of a mile or even less, the steamer and her tow could have rounded to and landed even in a hard wind from the south; and that not to do so in such a case would be bad seamanship.

Other witnesses testified that these piers increase the danger of the navigation; that vessels were very liable to be driven against such obstructions; that extraordinary precaution was necessary in going through them, and then, that "a man is liable to be beat at it."

Both the district and the circuit court held that the officers of the steamer were guilty of a wrongful act in attempting to pass between the piers of the bridge in the state of the weather at the time, and condemned the steamer. From this condemnation her owners appealed.

Mr. J. W. Cary, for the appellants, argued that it was plain from the fact that the vessel had put into Mendota for the exact purpose of *not* running while there was high wind, that all evidences of high wind must have disappeared before the vessels came out, that no wind did, in fact, disturb them until they got to where the bluffs recede; that there from the physical configuration of the land occasional gusts of wind might come unexpectedly through the gaps as through a funnel, though no high wind were stirring; that such was the case here; and that where such a gust did come through such a place it was a true peril of navigation.

Mr. N. J. Emmons, *Contra:*

Mr. Justice DAVIS delivered the opinion of the court. It is insisted that the loss occurred through a peril of navigation, which was one of the exceptions contained in the bill of lading, and that therefore the

carrier was excused from a delivery of the wheat. The burden of proof lies on the carrier, and nothing short of clear proof, leaving no reasonable doubt for controversy, should be permitted to discharge him from duties which the law has annexed to his employment. This burden has been assumed by the carrier, and the case was heard on the testimony introduced by the respondents, the libelant having called no witnesses.

It may be true, as the answer implies, that the boat would have safely made the passage if the wind had not driven her against the pier, but this does not solve the difficulty. The inquiry is whether the passage should have been undertaken at all in the general bent of the weather on that day. If the carrier had sufficient warning to put him on his guard, and chose to neglect it and take the chances of a venture, when common prudence told him there was danger in it, he cannot escape on the ground that the particular peril which finally overcame him was a sudden gust of wind. The general doctrine that a carrier is not answerable for goods lost by tempest has no application to such a case.

It is undeniable that the weather was boisterous during the after part of the day on which the loss occurred, and that the boat laid up at Mendota on account of the wind. It had at best only "abated" or "calmed down," when she left Mendota and proceeded on her voyage. There is a singular discrepancy in the testimony of the master and the mate as to the condition of the wind after the departure from Mendota, and as to where it was that the wind began to blow hard, the master swearing that there was no great wind until the boat met the *Julia*, and that this was but a quarter of a mile above the piers, the mate giving a very different account as to both facts. Both these officers had equal opportunities of judging, and there is nothing in the record affecting the credibility of either. In such a case the defense fails, for the respondents have no right to ask the court to prefer the testimony of one witness over the other, when there is nothing in the record to show that one is more reliable than the other.

Apart from this, there is enough in the evidence to establish satisfactorily that the weather had not cleared, nor the direction of the wind changed, and that the boat should either not have left her moorings at Mendota, or have landed at some proper point before the piers were reached. It won't do to say that the wind had moderated, and that the officers of the boat thought they could get through without trouble. They had no right to think so, for on such a day squalls were likely to arise at any moment, and it was bad seamanship, being forewarned, to attempt to go through such a dangerous place in the river. It is difficult at all times to make the passage of these piers, and especially so in sudden gusts of wind blowing from the south, which was the case on that day. And this difficulty is enhanced in the night-time and when the current, by reason of high water, is increased.

Any prudent officer would have stopped until the weather became calm. At any rate, it was the duty of the master of the boat in question to have done so, and failing in this duty, he is chargeable with the consequences of his negligence, which, in this case, was lamentable, for not only was the property in his charge destroyed, but a human life lost. The officers of steamers plying the Western waters must be held to the full measure of responsibility in navigating streams where bridges are built across them. These bridges, supported by piers, of necessity increase the dangers of navigation, and river-men, instead of recognizing them as lawful structures built in the interests of commerce, seem to regard them as obstructions to it, and apparently act on the belief that frequent accidents will cause their removal. There is no foundation for this belief.

Instead of the present bridges being abandoned, more will be constructed.

The changed condition of the country, produced by the building of railroads, has caused the great inland waters to be spanned by bridges. These bridges are to a certain extent impediments in the way of navigation, but railways are highways of commerce as well as rivers, and would fail of accomplishing one of the main objects for which they were created—the rapid transit of persons and property—if rivers could not be bridged. It is the interest as well as the duty of all persons engaged in business on the water-routes of transportation to conform to this necessity of commerce. If they do this, and recognize railroad bridges as an accomplised fact in the history of the country, there would be less loss of life and property and fewer complaints of the difficulties of navigation at the places where these bridges are built. If they pursue a different and contrary course, it rests with the courts of the country, in every proper case, to remind them of their legal responsibility.

DECREE AFFIRMED.

These decisions in the cases of the *Lady Pike* and the *Mollie Mohler* show how very important it is that Congress should pass laws in regard to bridges that will afford ample protection to navigation. Here is a bridge over a navigable stream, begun, without any authority of the laws of Congress, before 1866, and left in an unfinished state until 1870, with piers unreasonably close together, partly submerged at high water, oblique to the current, altogether making it "rashness to pass" such "a place of danger" in pursuit of the regular business of navigation at times when the other parts of the river were easily navigable to the best advantage. There seems every reason to believe that the bridge company was liable to damages, but under the rulings of the Supreme Court such redress is doubtful, and the steamboat-man is little able to carry on a suit against a bridge company, often backed up by a great railroad interest.

MEMORANDA UPON THE BRIDGES ON THE OHIO RIVER SUBSEQUENT TO THE WHEELING BRIDGE CASE.

The act of Congress making appropriations for rivers and harbors, approved July 11, 1870, provided in section 5 for the detail of three engineers, whose duty it shall be to examine all the bridges now erected or in process of erection across the Ohio River, and to report, &c.

The officers detailed were myself, General Godfrey Weitzel, and Col. W. E. Merrill. Our final report is given in the Annual Report of the Chief of Engineers for 1871, pp. 397–457.

The same assistant engineers, Mr. Cotton and Mr. Bentley, and the same methods were employed on the surveys of the Ohio River bridges that had been used upon the Mississippi.

The most prominent feature of interest here at that time was the Newport and Cincinnati Bridge, then in process of erection, which was being built as a pivot-draw, only 70 feet above low water, while the navigation interest claimed it should be by the law 100 feet above low water. The readiness with which the report on the Ohio can be consulted requires here no more than a reference to the distinctive features of the bridge. The law providing for the bridge between Cincinnati, Ohio, and Newport, Ky., grew out of that providing for the bridge at Steubenville, so that the debates in Congress on the subject which preceded the passage of that law became of interest, in order to ascertain the intention of the framers of that law.

All that is pertinent to this subject is given in the report of the Board of Engineers (Annual Report Chief of Engineers, 1871, pp. 435–440.) A minute description of the bridge as first designed is given in the same report, and it contains a recommendation that the constructors should be compelled to raise it to the height of 100 feet above low water for the security of navigation. The report of this board contains a fairly full account of all the bridges then built across the Ohio River. It also submitted a draught for a law regulating the bridging the Ohio River, with the reasons therefor.

Congress, by an act approved March 3, 1871, required the building of the Newport and Cincinnati Bridge, as recommended by the Board of Engineers, and provided that the bridge company might file a bill in equity, in the United States circuit court for the southern district of Ohio, for reimbursement for expenses in making the change, if in their first plan they had not acted unlawfully. This suit has been commenced, but, at the date of this report, not decided. The decision will be looked for with interest in connection with the matter of reserved right which the United States laws make to remedy any injury to navigation by future legislation, although the case of the Newport and Cincinnati Bridge is so pecular that it cannot have very general application as a precedent.

Congress, by an act approved December 17, 1872, established a general law for bridging the Ohio River, essentially as recommended by the Board of Engineers. Every proposition to bridge the Ohio River, under its provisions, must have the approval of the Secretary of War; and in the case of the bridge just below Cincinnati, the plan was submitted to a Board of Engineers consisting of General Simpson, Colonel Merrill, and Major Suter, Corps of Engineers. They decided that, at the site selected, a span of 500 feet was necessary to secure the clear navigable space which the law required. (Annual Report Chief of Engineers, 1876, Part II, p. 299). Under this decision, the city of Cincinnati built a clear span of 500 feet, standing on piers 100 feet above low water, upon the horizontal truss system, and without using steel or incurring any extraordinary expense. This is a great success for engineering in the interest of navigation.

The Board of Engineers, which reported upon the Ohio River bridges, has been again convened, to consider the question of a bridge at Evansville, where some new and important engineering questions have been raised.

Taken as a whole, Ohio River bridges have been provided, under circumstances of great difficulty, very thoroughly for the unobstructed navigation of that river.

The following is a list of the bridges on the Ohio River below Pittsburgh:

Steubenville, Ohio.—Railway bridge.
Wheeling, W. Va.—Highway suspension bridge over main channel.
Bellaire, Ohio.—Railway bridge.
Parkersburg, W. Va.—Railway bridge.
Newport and Cincinnati.—Railway and highway bridge.
Covington and Cincinnati.—Highway suspension bridge.
Cincinnati, Ohio.—Railway bridge.
Louisville, Ky.—Railway bridge.

MEMORANDUM UPON THE MISSOURI RIVER BRIDGES.

These have all been built since the time when this investigation was ordered, and generally under the same requirements as in the laws for bridging the Mississippi.

The less kindly nature of the Missouri in its changing banks and

shoals and the advantage of a less depth to the bed-rock made the option for a high bridge 50 feet above high water and spans (one at least) not less than 300 feet in the clear much more favorably received by bridge companies on the Missouri than on the Mississippi above their junction.

The gentle adaptable nature of the Mississippi River yields every advantage to free navigation, and yet submits to the worst conceivable obstructions without destroying them, although even here a limit to obstruction has been reached. The engineering of the bridges on the Missouri is, therefore, generally much better than that of the Upper Mississippi. For, while on the Mississippi all the bridges are on the low draw-bridge plan, except the highway bridge at Saint Paul, those on the Missouri, at Saint Charles, at Leavenworth, and Omaha, are high ones; 50 feet above high water.

Hence the conclusion is plain that the high-bridge alternative is not in itself impracticable, for it has been several times adopted in preference to the low-draw plan, under circumstances similar to the cases in which low draw-bridges have been given the preference upon the Mississippi.

Not having had the Missouri River bridges in my field of duty, I can give only a fragmentary account of them, which is as follows:

Saint Charles, Mo., railway-bridge. Three channel-spans 300 feet in the clear, 50 feet above high water; three 300-feet deck-spans on the right and one such on the left of the channel spans; approaches on iron trestles; maximum grade, 1 to 100. This is an admirable structure, designed and built by Smith & Latrobe, Baltimore Bridge Company. It occupied three years in building, being finished in 1871, at a cost of $1,797,186.19. This bridge was designed by General C. Shaler Smith, without any limiting provisions in the United States laws.

Boonville, Mo., railway draw-bridge, 10 feet above high water, with draw-openings 160 feet in the clear. Built with unexampled dispatch, and finished in January, 1874. (See Van Nostrand, vol. 10, p. 91.) General W. Sooy Smith, engineer.

Kansas City, Mo., railway draw-bridge, 10 feet above high water, with draw-opening 160 feet in the clear. Finished in July, 1870, Mr. O. Chanute, engineer. Full account by Mr. Chanute, published by Van Nostrand, 4to, with illustrations. This bridge is reported upon by Major Suter, Corps of Engineers, in Annual Report of Chief of Engineers for 1869, pp. 304–306.

Leavenworth, Kans., elevated railway-bridge built 50 feet above high water, one span of 340 and two of 315 feet (probably from centers). Finished in 1872. General W. W. Wright, engineer. Foundation sunk to bed-rock.

Atchison, Kans., railway draw-bridge; clear openings of 160 feet. Probably 10 feet above high water. Recently built.

Saint Joseph, Mo., railway and highway draw-bridge, with clear openings of 160 feet each, one span of 80 feet and three of 300 feet. Foundation sunk to bed-rock by plenum pneumatic process. Finished in June, 1873. Mr Eddy D. Mason, engineer.

Omaha, Nebr., elevated railway bridge 50 feet above high water. One channel-span, 300 feet in the clear, other spans, 250 feet. Finished in 1872. General W. Sooy Smith, engineer for the foundations, which are tubes, sunk by pneumatic process to bed-rock.

List of bridges on Missouri River, authorized but not built.

At Glasgow, Mo.
At Lexington, Mo.
At Brownville, Nebr.
At Nebraska, Nebr.
At Sioux City, Iowa.

ABSTRACT OF LAWS FOR BRIDGING THE OHIO, MISSISSIPPI, AND MISSOURI RIVERS.

Act of Congress approved August 31, 1852, declared the suspension bridge over the Ohio River at—

WHEELING, VA., to be a lawful structure and a post-road. The highest of point this bridge is 91½ feet above extreme low water, and 48 feet above highest water; for a width of 155 feet it has a height of 91 feet above low water. The distance between centers of towers is 1,010 feet, and between the faces of the abutments 980 feet.

Act approved July 14, 1862, authorized the building of a bridge at—

STEUBENVILLE, OHIO, or at any point over the Ohio River above the mouth of the Big Sandy River. The provisions for the Steubenville bridge were that it should leave an unobstructed headway in the channel of the river of not less than 90 feet above low-water mark, and an unobstructed width of not less than 300 feet between the piers next to said channel or water-way; and one of the spans next adjoining thereto shall not be less than 220 feet in length. If constructed with a draw it should be under the limitations of the section containing general provisions. This section allowed the bridge to be built either as a high bridge or draw-bridge. If built as a high bridge it should be not less than 90 feet above low water over the channel, nor in any case less than 40 feet above extreme high water, channel-span not to be less than 300 feet in width, and one of the next adjoining not less than 220 feet. If built as a draw-bridge the same shall be constructed with a span over the main channel 300 feet in length and not less than 70 feet above low water mark, and one of the next adjoining spans not less than 220 feet, and also that there shall be constructed a pivot-draw in every such bridge in a navigable part, with spans of not less than 100 feet on each side of the pivot.

Act approved July 2, 1864, entitled

An act to amend an act entitled "An act to aid in the construction of a railroad and telegraph line from the Missouri River to the Pacific Ocean, and to secure to the government the use of the same for postal, military, and other purposes," approved July first, eighteen hundred and sixty two,

gave authority to the Union Pacific Railroad Company to construct bridges over the Missouri River and all other rivers, for the convenience of said road; *provided*, that the bridges be constructed with suitable and proper draws for the passage of steamboats, and in such manner as not to impair the usefulness of said rivers for navigation to any greater extent than such structures of the most approved character necessarily do.

By section 13 of the *act approved July* 1, 1862, the Hannibal and Saint Joseph Railroad Company was authorized to extend its road from Saint Joseph, *via Atchison, Kans.*, to unite with the road through Kansas upon the same terms and conditions as provided for the Union Pacific Railroad Company.

Act approved February 17, 1865, declared that the bridge across the Ohio River, from—

CINCINNATI, OHIO, TO COVINGTON, KY., when completed shall be a lawful structure and post-road (Highway Suspension Roebling's).

Act approved February 17, 1865, amended the act approved July 14, 1862, so as to authorize the construction of a bridge over the Ohio River at the head of the Falls at—

LOUISVILLE, KY., provided that it shall be 56 feet above low water mark and with three draws sufficient to pass the largest boats navigat-

ing the Ohio River; one over the Indiana chute, one over the middle chute, and one over the canal. *Provided*, that the spans shall not be less than 240 feet in width, except the draw-spans; the draw-spans over the Indiana and middle chutes shall be 150 feet each side of pivot, and the draw over the canal 90 feet. (The company built a better bridge. See Annual Report Chief of Engineers, 1871, p. 419.)

By act approved July 25, 1866, bridges were authorized to be built at—

QUINCY, ILL.,
BURLINGTON, IOWA.,
HANNIBAL, MO.,
PRAIRIE DU CHIEN, WIS.,
KEOKUK, IOWA,
WINONA, MINN.,
DUBUQUE, IOWA,
SAINT LOUIS, MO.,
} over the Mississippi River.

KANSAS CITY, MO., over the Missouri River.

The general provisions of this act were, that if built as high bridges they should be 50 feet above extreme high water mark, with spans not less than 250 feet in length, and one main or channel span not less than 300 feet in length; if built as draw-bridges, they shall have two draw-openings of not less than 160 feet in the clear, and next adjoining spans of not less than 250 feet, and should be 10 feet above high and 30 feet above low water. It provided that the bridge at Saint Louis should not be a suspension or draw-bridge, but of continuous or unbroken spans, with the bottom chord 50 feet above the city directrix at its greatest span; that it should have at least one span 500 feet in the clear or two spans of 350 feet in the clear; that no span over the water at low-water mark should be less than 200 feet in the clear.

Act approved February 27, 1867, declared the railway bridge over the Mississippi River at—

CLINTON, IOWA, to be a lawful structure and post-route.

Act approved March 2, 1867, appropriated $200,000 for building the—

ROCK ISLAND BRIDGE. It provided that the ownership should remain in the United States; that the Rock Island and Pacific Railroad Company should have the right of way over said bridge and island for purposes of transit, upon the condition that the said company shall, before any money is expended, agree to pay half the cost of said bridge and half the expense of keeping it in repair.

Act approved February 21, 1868, authorizing the Southern Minnesota Railroad Company to build a bridge at—

LA CROSSE, WIS., subject to the terms, conditions, &c., of the act approved July 25, 1866, authorizing bridge at Quincy, Ill., &c.

Act approved July 20, 1868, authorized the building of a bridge over the Missouri, at—

FORT LEAVENWORTH, KANS., and one at SAINT JOSEPH, MO. The bridges must be 50 feet above extreme high-water mark to the bottom chord, and have spans of not less than 250 feet in the clear.

Act approved July 20, 1868, provides that the bridge at—

SAINT LOUIS, MO., shall have one span of at least 500 feet clear between the piers.

Act approved March 3, 1869, appropriated $500,000 for the construction of the—

ROCK ISLAND BRIDGE.

Resolution approved March 3, 1869, gave consent to the erection of a bridge over the Ohio, from—

CINCINNATI, OHIO, to NEWPORT, KY.; provided that the bridge be

built with an unbroken or continuous span of not less than 400 feet in the clear from pier to pier; in all other respects in accordance with conditions, &c., of an act to establish certain post-roads, approved July 14, 1862.

Joint resolution approved April 7, 1869, authorizes the building of a bridge at—

PADUCAH, KY., with a continuous span of not less than 400 feet in the clear; in other respects, in accordance with act approved July 14, 1862.

Act approved July 11, 1870, directed the Secretary of War to detail three engineers to examine all bridges now erected or in process of construction across the Ohio River, and to report whether such bridges will interfere with the free and safe navigation of the river, and, if they do, to report what extent of span and elevation above water will be required to prevent such obstruction, and an estimate of cost to change them.

Act approved July 14, 1870, amending act approved July 20, 1868, allowing the bridge at—

SAINT JOSEPH, MO., to be built on the terms and subject to limitations of the act of Congress approved July 25, 1866, provided if built as a draw-bridge the spans of the draw shall not be less than 200 feet in the clear on each side of the central point.

Act approved March 3, 1871, made it unlawful to proceed in the construction of the bridge over the Ohio River from—

CINCINNATI, OHIO, TO NEWPORT, KY., now being constructed, unless so constructed that the channel-span of 400 feet, as located, shall have a clear headway at low water of 100 feet below any point of the span. In such case no draw would be required. Further required that proposed changes by the company should be submitted to the Secretary of War for his approval. It also provided that the company could, after making the changes, file a bill in equity in the United States circuit court, and gave the courts jurisdiction.

Act approved February 24, 1871, authorized the construction of a railway and highway bridge over the Missouri River at—

OMAHA, NEBR., under the provisions of the act approved July 25, 1866, authorizing the bridge at Quincy, &c., provided that if constructed as a draw-bridge it shall have draw-spans of not less than 200 feet in the clear on each side of the pivot-pier.

Act approved March 3, 1871, authorized the bridging of the Mississippi River at—

LOUISIANA, MO., and provided that if built with unbroken and continuous spans it should not be of a less elevation than 50 feet above high water mark to the lower chord of the bridge, nor should the spans over the main channel be less than 350 feet in length, and provided that if built as a draw-bridge the draw should be over the main channel with spans not less than 200 feet in length in the clear.

Section 6 authorized the construction of a bridge over the Missouri River within 9 miles of—

GLASGOW, MO., provided that the said bridge shall be made with unbroken and continuous spans of the same height and lengths as provided for a high bridge at Louisiana, Mo.

Act approved March 3, 1871, appropriated $500,000 for completing the ROCK ISLAND BRIDGE; it being an unexpended balance covered into the Treasury.

Act approved March 5, 1872, authorized the building of a railway and highway bridge by the "Saint Joseph Bridge Building Company" at—

SAINT JOSEPH, MO., either as a high bridge or low draw-bridge; if high not less than 50 feet above extreme high water mark.

Nor shall the spans of said bridges be less than 350 feet in length, * * * and the main span shall be over the main channel of the river and not less than 300 feet in length.

If built as a draw-bridge, the provisions are the same as in the act approved July 25, 1866, authorizing the bridge at Quincy, &c. This act provides that a plan of the bridge must be submitted to the Secretary of War for his approval. The company shall not assign the charter which it now holds by assignment from the Saint Joseph and Denver City Railroad Company, nor construct any other bridge.

Act approved April 1, 1872, authorized the building of a bridge over the Mississippi River within 15 miles of—

CLINTON, IOWA, not to interfere in any manner with approaches or piers of the bridge now constructed at Clinton, under the limitations as to dimensions of spans as provided in the act approved July 25, 1866. All railroad companies desiring to use it shall be entitled to equal rights in the passage of it, upon terms and conditions prescribed by the Secretary of War.

Section 5 provides that the Secretary of War shall have power to make regulations for the security of navigation, and the bridge shall be changed at the expense of the owner.

Section 6 authorizes a bridge at—

MUSCATINE, IOWA.

Section 7 authorizes a bridge at any point between the counties of—

WHITESIDES AND CARROLL, ILLINOIS, and JACKSON AND CLINTON, IOWA.

Section 8 authorizes a bridge to be built at—

LA CROSSE, WIS., by the Milwaukee and Saint Paul Railroad Company.

Act approved May 1, 1872, amends act approved March 5, 1872, but did not change any of the required lengths and heights of span.

Act approved May 11, 1872, authorized a bridge at—

BOONVILLE, MO., to be built under the requirements of act approved July 25, 1866.

Act approved May 15, 1872, authorized a bridge over Lake Saint Croix at—

HUDSON, WIS.; draw to be 320 feet long over all, with two spans of 140 feet in the clear, for the passage of boats; one span, 136 feet in the clear, for the passage of rafts. No provision was made as to height.

Act approved May 17, 1872, authorizes a railway and highway bridge to be built at—

QUINCY, ILL., under the same provisions as in act approved April 1, 1872, for a bridge at or near Clinton.

Section 7 authorizes a bridge at

WARSAW, ILL. A provision of the act was that this bridge be commenced within eighteen months.

Act approved May 25, 1872, authorizes a bridge at—

FORT MADISON, IOWA, under the provisions contained in act approved April 1, 1872, for a bridge at Clinton, &c.

Act approved June 4, 1872.—All bridges hereafter constructed over the Mississippi River, under authority of any act of Congress, shall be subject to all the terms, restrictions, and requirements as to length and height of spans, &c., of the act authorizing the bridge at or near Clinton, Iowa, approved April 1, 1872.

Act approved June 4, 1872, authorizes the Davenport and Saint Paul Railroad Company to pass their cars over the bridge at Rock Island, under certain provisions.

Act approved June 4, 1872, authorizes the building of a railway and highway bridge at—

NEBRASKA CITY, NEBR., under the provisions of act approved July 25, 1866. Section 2 provides that the charter shall be for the use and benefit of any person or corporation who shall complete the bridge, and that the said corporators may be compelled to make the transfer of the charter by any court having jurisdiction.

Provided, That the said Nebraska Bridge Company and their associates shall fail to commence in good faith the erection of said bridge within one year from the passage of this act and complete the said bridge without unnecessary and unreasonable delay in accordance with the provisions of this charter.

Act approved June 4, 1872, authorizes building a railway bridge across the Missouri River at—

BROWNVILLE, NEBR. If high, 50 feet above high water; spans, 250 feet; main span, 300 feet; if a draw-bridge, draw-openings not less than 200 feet; adjoining spans, 250 feet; 10 feet above high-water.

Act approved June 10, 1872, authorizes a railway bridge to be built at or near the city of—

RED WING, MINN., under the provisions of act of July 25, 1866.

Act approved December 17, 1872, authorizes the bridging of the Ohio River, for railroad or other purposes, by any one having authority therefor, upon compliance with the provisions and requirements of this act. Every bridge above the mouth of the Big Sandy shall have at least one span of a height of not less than 90 feet above low water and of not less than 40 feet above local high water; that this high span shall give a clear opening of at least 400 feet between the piers, and shall be placed over the main channel. If the high span is not over the low water channel, suitable arrangements to be made elsewhere to permit the passage of single boats at low water. All bridges over the Ohio below the Covington and Cincinnati suspension bridge shall have in addition to the high span prescribed above a pivot-draw with two clear openings of 160 feet each. If the conditions of this act cannot be complied with the Secretary of War shall appoint a board of three experienced officers of the Corps of Engineers to examine the case, and may on that recommendation authorize such modifications in the requirements of this act as will permit the construction of the bridge. All bridges over the Ohio shall maintain such lights as may be required by the Light-House Board.

This act authorized the building of one bridge at—

WHEELING, W. VA., with a span over the main channel of not less than 350 feet in length.

Joint resolution number ten, approved April 7, 1869, authorizing a bridge at—

PADUCAH, KY., was repealed by this act.

Standard steam-pressure for tow and freight boats on the Mississippi River and tributaries changed from 110 to 150 pounds by this act.

Act approved March 3, 1873, authorizes the Saint Clair and Carondelet Bridge Company to bridge the Mississippi from the southern part of—

SAINT LOUIS.—The bridge must have two spans over the main channel of not less than 500 feet in the clear at low water mark, no span over the water at low water mark to be less than 250 feet in the clear. The elevation of the bridge over the main channel shall not be less than 100 feet above low water mark, measuring to the lowest part of the superstructure, or in case of arch spans, to the lowest point of the center of

the arch; that it shall have two railway-tracks, two highway-tracks, and two foot-walks of not less than 8 feet in width.

Act approved March 3, 1873, authorizes a railway-bridge over the Missouri River at—

LEXINGTON, MO., to be built under the same provisions as contained in act approved July 25, 1866.

Act approved June 6, 1874, legalized the railway and ponton bridge across the Mississippi River at—

PRAIRIE DU CHIEN, WIS.—Section 4 of this act provides that the bridge authorized at or near—

CLINTON, IOWA, by act approved April 1, 1872, may be constructed as a pile and ponton bridge, with a draw not less than 408 feet in width.

Act approved June 22, 1874, authorized the Milwaukee and Saint Paul Railway Company to construct a bridge at a point heretofore selected at—

LA CROSSE, WIS.; a board of engineers to be convened to report what accessory works are necessary to secure a straight channel-way for navigation; the board to determine the location of piers and height of bridge; company not to proceed with the building until report of the board is approved by the Secretary of War; superstructure not to be commenced until accessory works are constructed; a provision that the said company shall not charge more than $3 a car for each freight-car transported across said bridge.

Act approved June 23, 1874, appropriated $23,400 for—

ROCK ISLAND BRIDGE, for alterations and repairs and additional machinery (for draw of bridge), and for care and preservation, one-half of which sum to be reimbursed by the Chicago, Rock Island and Pacific Railroad Company.

Act approved March 3, 1875, act amendatory of the act approved March 3, 1873, authorizing bridge over the Mississippi at—

SAINT LOUIS, MO., allows two straight continuous spans of not less than 450 feet in the clear. Section 2 requires the company to close Cahokia Bend if the site on plan numbered "2" submitted to the Secretary of War be accepted.

Act approved March 3, 1873, authorized a ponton wagon-bridge across the Mississippi River at—

DUBUQUE, IOWA, subject to all the terms, &c., of act legalizing a ponton railway-bridge at Prairie du Chien, Wis., approved June 6, 1874, subject to the provision that it shall have a draw 500 feet wide and that plan and location shall be subject to the approval of the Secretary of War.

Act approved July 6, 1876, authorizes the city of—

LA CROSSE, WIS., to construct a pile and ponton bridge across the Mississippi River, subject to all the terms of act legalizing the Prairie du Chien railway ponton bridge approved June 6, 1874, with the modifications that it shall have one draw of not less than 400 feet, and that plans and location must first be submitted to the Secretary of War for his approval.

Act approved July 8, 1876, authorizes the Nebraska City Bridge Company to build a ponton railway-transit and wagon bridge across the Missouri River at—

NEBRASKA CITY, NEBR., with a draw 300 feet wide; design and drawings of the bridge and a map of the location for one mile above and one mile below the bridge shall be submitted to the Secretary of War for his approval before the bridge shall be built.

Act approved August 15, 1876, authorizes the Sioux City Bridge Company to build a railway and highway bridge over the Missouri River at—

SIOUX CITY, IOWA.—It may be built as a high bridge 50 feet above extreme high water, all spans 300 feet; or as a draw-bridge, same dimensions, &c., as act approved July 26, 1866. If the company elect, the Secretary of War may authorize the building of a pile or ponton bridge subject to the restrictions in the act legalizing the Prairie du Chien bridge, approved June 6, 1874, except that it shall have one draw 400 feet wide in the clear; plans of bridge and location to be subject to the approval of the Secretary of War.

CHAPTER VI.

GENERAL ACCOUNT OF THE WAY THE SURVEYS AND INVESTIGATIONS HAVE BEEN MADE.

Description of surveys made in 1866, '67, '68, '69, and '76—Circumstances under which the maps and report were prepared—LIST AND DESCRIPTION OF ORIGINAL MAPS—COMPILED MAPS ON A SCALE OF TWO INCHES TO A MILE—Map on scale of an inch to six miles—LIST OF MAPS COLLECTED AND USED IN THE COMPILATION.

Surveys in 1866.—This description of surveys includes not only those made at bridge sites, but such as were made for the purpose of improving places of difficult navigation, more particularly of the river between the Falls of Saint Anthony and Rock Island. The subject of improvement will be treated in a separate report, but the surveys are all described here, as they were really included in the requirement of the bridge investigation "to survey the whole river." The same parties did the field-work for both purposes. Mr. J. P. Cotton, civil engineer, was from the first employed on this work, and for much the larger portion of the time he was in charge of these surveys. He has, also, with other assistants, under my direction, prepared all the maps and other drawings, and aided me in every part of this work.

The short time remaining between my arrival in Saint Paul, in August, 1866, and the close of the season, coupled with the fact that my report upon these surveys had to be submitted to Congress at its next session, in December, precluded the possibility of making a continuous survey of more than a small portion of the river upon which I was to report. I therefore concluded to make a reconnaissance of the whole river from Saint Anthony to Saint Louis, and to make detailed surveys at points where navigation was obstructed, and at bridges, and at proposed and probable sites of bridges.

For this reconnaissance, the steamer G. B. Knapp was chartered at $1,000 per month. She was a new steamer, built to run between Stillwater, Minn., on Lake Saint Croix, and Saint Paul, Minn. Her draught, when light, was only about 20 inches. The light draught enabled her to run in any channel that could be navigated by freighting steamboats. The boat was in charge of a captain, a pilot, two engineers, fireman, and deck-hands. Difficulty, as usual, was found in organizing a party to make the instrumental surveys. This was the first work in that section of the country requiring engineers possessed of practical knowledge in river surveying, and want of time prevented bringing them from other places.

Mr. C. C. Smith, an engineer of ability, whom I employed, succeeded in getting together the following party, viz: T. P. Gere, J. P. Cotton, A. D. McSweeny, C. H. Conwell, and H. D. Van Pelt. These men had come to this part of the country for various reasons, and had been en-

gaged upon railroad surveys. One of them, Mr. Conwell, with mental acquirements and aims well fitted for our work, had come for his health, which he could not secure, and his loss was much felt in my subsequent work. Taken as a whole, the party at the outset was a make-shift, such as every engineer has to use, when his chance for success is only to do the best he can. They all did the best that could be expected in this line of work, and some of them succeeded so well as to be highly appreciated afterward upon other river work, where they are now employed. The whole party consisted of forty-one persons, as follows: 1 engineer in charge, 5 assistants, 4 chainmen, 4 flagmen, 1 steersman, 10 axmen, 2 rodmen, 10 boatmen, 2 cooks, 1 watchman, 1 steward. Other men were employed from time to time in the place of those who were sick or disabled by accident; so that the effective party usually numbered 36 to 40 men. It was essential to have men who could handle and row a boat, so that in hiring men we were confined to this class. Trouble of course was had with them, the most of whom were steamboat hands, never long content at one thing or in one place. The party would barely get into working order when it would be crippled by one or more of the boatmen leaving. New ones employed in their places had to be instructed. It is the old story, and only mentioned here to show that we were no better placed than others had been. To lodge this party, a flat-boat, which had been built to carry produce down the river, was purchased and fitted up. This boat answered very well for the purpose, although it was too small for comfort. It was purchased for $650, and fitted up for $200 additional. There were employed upon this boat two men to take care of it, two cooks, one steward, and one watchman. A transit-line was to be run on each bank as near the water's edge as practicable, the topography along the line being noted by the transitman; stakes to be set at hundred-feet intervals to enable the sounding party to fix the ends of their sounding lines. "*Towheads*" (a name given to an embryo island, or the last vestiges of one that is washing away) were located by triangulation. Mr. Gere was given charge of one of these parties, and Mr. McSweeny the other at the first start. Mr. Gere performed his new duties with success and he remained during the first season.

Each transit party was made up of 1 transitman, 2 chainmen, 3 axmen, 2 flagmen, and an instrument carrier.

The level line was confined to one bank. It was to be continuous, touching the water surface at intervals of not more than 1,000 feet, and, if practicable, as often as each 500 feet. All high-water marks were to be connected with it, and special pains was enjoined to search for them. It was found that the knowledge of those living on the river, concerning the level of high or low water, was unreliable, and it was only in rare cases that definite marks could be found. When good marks were found there was frequently an uncertainty as to the knowledge of the date. Bench-marks were to be established at intervals of not more than one mile. Trees had to be used generally as a matter of necessity, and if in the future they cannot be found, attention must be paid to this narration of the circumstances. Whenever the survey included towns, the bench-marks were to be made upon the most presumably permanent objects that could be found in them within practicable distances of the surveyed lines. Fortunately this delicate and important work was at the outset assigned to Mr. Cotton. The level party consisted of a leveler and two rodmen.

The topographer was entrusted with getting the character of the bottom-lands, terraces, and bluffs adjacent to the lines run along the

river. When the survey reached a part of the river where it was divided into two or more channels by islands, he was placed in charge of a party to meander the islands with compass. He also assisted in locating submerged bars, and in all the various measurements of special localities, in velocity and discharge observations, &c. This position was given to Mr. C. H. Conwell. The topographer was assisted by two chainmen and as many axmen as special occasion required.

Sounding-lines were run across the river as often as every 500 feet, usually in a direction diagonal to the shore. Each line was started from a point on a transit-line, this point being noted in the sounding-book by the recorder, and the distance from the line to the first sounding estimated. The boat was then rowed at a uniform rate, and soundings were taken at regular intervals, as near as could be estimated; on reaching the opposite bank, the recorder noted the station of the transit-line, and estimated the distance from the last sounding to it. When soundings were made between the shore and islands, the lines were run to the points on the island that had been fixed by triangulation. The sounding-party consisted of a recorder, sounder, and four oarsmen.

In this method of sounding a river a great many soundings can be made, but it very imperfectly fixes their position on a map, even when the greatest effort is made to secure uniformity in the time of sounding and rowing. But this attempt at cadence requires the soundings to be made at intervals which often miss the most important features of the bottom, and the pole of convenient length sometimes does not reach the bottom in deep places. Sometimes the grounding of the boat on shoals and when approaching the shore destroys all uniformity in the work and the regular spacing of the soundings on the lines marked is wrong. One tenth of the number of soundings made with judgment, where the actual position is fixed, is of far greater value. We have found that with an instrument having a micrometer attachment to give the distance by measurement of the image of a rod of known length, and a compass bearing to the place, will fix the point well enough for ordinary purposes. This method serves well to map the crests of sand bars; and then a few soundings in the deep intervening parts are all that is required to show the actual state of the river.

Reductions of the depths to any one plane, in shoal rivers with sandy bed, cannot bed one with any propriety, for the bed changes with the rise and fall of the water, and has no permanent form. At best it is condition that we ascertain, and for engineering purposes the depths have no value beyond a knowledge of the ruling navigable depth. Given the volume of water and the slope and the kind of bed, we can deduce the navigable capacity a stream can be made to have. This is a fact that is not generally known or apprehended.

Gauges to measure the rise and fall of the river during the survey were established at Minneapolis, Minn., above the falls, Saint Paul, Minn., Winona, Minn., Prairie du Chien, Wis., and Clinton, Iowa.

Mr. Smith was directed to commence work at Fort Snelling (at the mouth of the Minnesota River), to instruct the assistant and men in the duties required of them, during the time I was organizing and instructing the parties for the examination and report upon the Minnesota River, the Cannon and Zumbro Rivers, and upon the Fox and Wisconsin Rivers. He made a commencement on the 13th of September. The survey was continued under the direction of Mr. Smith, until the 21st of September, when he received, and with my permission accepted, the offer of more permanent employment on the Minnesota Valley Railroad. The party was then placed in charge of Mr. H. C. Long, civil engineer.

Before I joined the party a continuous survey had been made of the river from Fort Snelling to Red Rock, a distance of 13 miles; but no reliable current measurements had been made.

On the 23d of September, all of the parties for the other river surveys in my charge having been started, I closed my office in Saint Paul and went on board the steamer Knapp to give personal attention to the surveys and examinations of the Mississippi. The quarter-boat was taken in tow by the steamer Knapp. Capt. N. F. Webb of steamer Itaska, of Northwestern Union Packet Company, was engaged to point out those places at which the greatest obstacles to navigation were usually found. His long experience as captain of steamers on this river made him familiar with the needs of navigation as well as the difficulties attending it. His good sense and kind, manly character, endeared him to us all. He subsequently lost his life by an accident in the public service.

Proceeding on board the *Knapp* to Red Rock, the quarter-boat was taken in tow and the reconnaissance sketches begun. One of these was made by me to acquaint myself with the character of the river. Distances were estimated, and the local directions were taken from the positions of the sun, checked occasionally by a compass. My attention was specially given to noting characteristics of the river. The widths were checked occasionally by triangulation. This course of observation was a valuable means of instruction and the record was useful for future reference. I would advise everyone put in charge of a river so little known as this was to pursue such a course, for it gives one ideas fresh from nature, and enables him to appreciate the views of others.

The other sketch made by us on the steamer Knapp was made by Mr. H. Custer. In this, much more care for accurate representation of course and distance was attempted. The distances were estimated by him at the rate of the boat's motion, and his courses were taken by a compass all the time. At the same time soundings were being made and recorded. The result when worked out was a disappointment to us. The rate of a steamboat on the Upper Mississippi in low water is exceedingly variable. On approaching a shoal the valves of the engine will be shut off so that the vessel barely moves, being kept, as it were, balanced in the control of the pilot, to go either back or forward as may be best. During this time the steam accumulates in the boiler, and when the shoal is passed full power is let on urging the boat on rapidly until the next shoal requires the repetition of the same exercise of judgment. Thus it is, measured by time, a steamboat may be longer passing one or two hundred feet of shoal than in passing 1 or 2 miles of deep pools. Mr. Custer had not had enough experience at this kind of river work to make due allowances for the ever varying rates. The steamboatman himself, by long experience and observation, judges very well about this matter of average speed, but I have found not only on the Mississippi, but on the Missouri in 1856, that even the pilots much overrate velocity.

We found the carefully prepared sketch of Mr. Custer nearly worthless, and have never used it to any extent. Another disclosure was that the man sounding while the boat was in motion, always found a great deal more depth of water than there really was. I mention this as a caution against receiving reports of such soundings where any important conclusion depends upon them. We stopped awhile at Robinson Island and bar, where a base line was measured and the features of the island and bar determined. The next point at which surveys were made was at Hastings, Minn., where a railroad bridge had been proposed. Here the volume of the river was measured with mid-depth

floats. Between Hastings and Prescott, particularly in the vicinity of Prescott Island, there were very bad sand bars that greatly obstructed the navigation of the river, and the survey was made continuous between the two places, a distance of 2½ miles. The position of the sand bars was fixed by triangulation. This was the system used in locating bars throughout the survey of this season. An examination was made of Lake Saint Clair up to Stillwater, and a map made of the narrow places at Catfish Bar, and opposite the mouth of Willow River. The volume of discharge from the lake was also measured.

At the mouth of the Cannon River, the party made a short survey, and measured the volume of water flowing from this small river, because it was one of the rivers upon which I was to report. A survey was made of the west or Wacouta channel, one of the three mouths by which the Mississippi enters Lake Pepin. This is the most favorable one for navigation, although sometimes too shoal. The entrance to the others from the lake is more difficult. The middle channel was sketched and sounded out by the steamer Knapp, but the northern one was not visited this year for want of time.

The party then proceeded to the foot of Lake Pepin, where a continuous survey of about 13 miles of river was made. This part of the river includes the mouth of the Chippewa River and some of the most troublesome bars on the Mississippi below Lake Saint Croix. Both banks were surveyed, the larger islands meandered, and nearly all the sloughs and all of the navigable channels sounded out. All bars having a defined outline were located by triangulation. A continuous line of levels was run the whole distance, particular pains being taken to observe the difference in level of the water surface above and below the crests of bars. Bench-marks were established and all high water marks found, connected with the line of levels. The channels below Alma, Wis., were also run out and sketched in the same manner, and at Alma the volume was measured with mid-depth floats.

While the party was making this survey, I took passage on a very small steamboat, drawing about 12 inches, and ran up the Chippewa River to the head of the Chippewa River delta, making sketches on the way. The little steamboat had much difficulty in navigating. She was poled around sharp turns, and the passengers sometimes went ashore and walked. We returned in a skiff by the other mouth known as "Beef Slough." This slough is deeper than the former channel for half the way down, when it is lost in numerous diverging channels choked with trees, and barely passable for a canoe. It furnishes a most interesting subject for study. Lake Pepin is a consequence of the deposit of sand from the Chippewa River.

On the 1st of October surveys were made in the vicinity of Minneiska, including the mouth of the Whitewater River, and at Chimney Rock Bar. On the day after, at Rolling Stone Bar, three miles above Fountain City, Wis.

The party then proceeded to Winona, at which place a railroad bridge had been authorized by Congress. The survey began on the 3d, and was completed on the 4th of October. It extended over about 4 miles of the Mississippi between the mouth of Straight or Rolling Stone Slough and a point about 1 mile below the city. The direction and velocity of the current were determined in two places.

We then went to La Crosse, Wis. Here the building of a railroad bridge had been considered by the Southern Minnesota Railroad. We commenced to survey about 2 miles above, and extended to some distance below the town, in order to include all probable bridge sites; in *all, about 4½* miles. The volume of the whole river was measured at

La Plume Island. Velocities of current were measured in several other places, giving us the volume of the main river at La Crosse.

On the 7th of October, we made a small survey in Coon Slough and at the town of Bad Axe, Wis.

At Prairie du Chien, another railroad bridge had been authorized, and a survey was made, commencing at the head of the island 2 miles above the town, and extending down so as to include the mouth of the Wisconsin River. The survey was made to cover the probable location of the bridge. The bars at the mouth of the Wisconsin River were located by triangulation, and the survey lines were run up that river for a short distance. Current-measurements were made at several places. This survey was completed on the 10th of October.

On the 11th of October, surveys were made of a small extent of river at Guttenberg, Iowa, and at Cassville, Wis., where navigation had been obstructed by sand-bars during low water in previous years, and some abortive attempts at improvement had been made.

The next point surveyed was at Dubuque, Iowa, where Congress had authorized another railroad bridge. The survey was commenced on October 12, at the State line between Wisconsin and Illinois, about one-half of a mile above Dunleith, Ill., and extended to the mouth of Catfish Creek, 2 miles below Dubuque, Iowa, the whole length of river surveyed being about 4½ miles, and it was finished on October 14. The volume of discharge and the direction and velocity of the current were measured here.

The next survey made was at the railroad bridge at Clinton, Iowa, on October 15, 16, and 17. The survey commenced at Fulton, Ill., and extended to Beaver Island below Clinton, a distance of 3 miles, and was finished October 17. It included a complete survey of the bridge, both of its substructure and superstructure. A fuller set of current-observations were made here than at any previous place. The method was an improvement upon our previous practice and was the result of experience. It was followed in all our subsequent current-observations at bridge sites. The English engineers on the International Bridge over the Niagara at Buffalo in 1870 adopted it from us, and Mr. Gurowski gives an account of it in his interesting report on that bridge. As a simple and reliable method it seems to leave nothing to be desired, giving both direction and velocity, and a description of it is inserted here.

Floats of joist 4 to 8 feet long and 2 inches by 3 inches in section were used, sunk to near the surface of the water, bearing little flags to make them readily seen. They were started some distance above the bridge, and allowed to pass through it, their positions being determined every thirty seconds by angles measured from each end of a measured base on shore. A time-keeper, with watch in hand, stood midway between the two observers, and five seconds before the even half minute he called "Ready!" The observers at the theodolites directed the telescopes to the flag of the float and kept it in view as it floated until the time-keeper called "Time!" at the even half minute. The angles were then read and recorded in the note-books. Similar observations were made above and below the bridge. Where the distance between the theodolites was long, or where there was noise so that the voice could not be heard, flag-signals were used to denote "ready" and "time."

It is well to state here, in view of the expensive and troublesome way in which these floats are sometimes made, that it can be done very simply. A bag with a slit left in it large enough to insert the hand is tied at the bottom end of the stick used as a float, into which sand, gravel, or stone can be inserted until the proper submergence is obtained. A sliver from a shingle makes a good flag staff, which can be

stuck in the upper end in a small hole bored for the purpose. Little strips of light cloth of different colors should be at hand to be used as flags, and small carpet-tacks will readily fasten them to the little flag-staff. These are so cheap that after using they may be thrown away if it is expensive to pack them up or transport them to another place.

On October 17, the steamer Knapp towed the quarter-boat, with party, to Le Claire, Iowa. The river was at this time so low that the crossing of the rapids was only attempted by very small steamers, and with these it was difficult to do, and attended with considerable risk. In view of this, and of the uncertainty of being able to get back with the Knapp if the river should continue to fall, I decided to turn over the quarter-boat to General J. H. Wilson, Corps of Engineers, discharge a portion of the party, send the steamer Knapp back to Saint Paul, and make such surveys as were required below this point with a smaller party, transporting it from place to place by the regular packet steamers or in our own skiffs. All surveys made up to this date had been rapidly plotted in the evenings and while the quarter-boat was being towed from place to place. These plats and the note-books were intrusted to Assistant McSweeney, with direction to return to Saint Paul on board the steamer Knapp.

From Le Claire to Saint Louis (except over the Rock Island Rapids and Des Moines Rapids), the sketching was continued by Mr. Custer from the pilot-house of the steamers running regularly on this part of the river. He thus managed, by several changes, to sketch the whole river by daylight, but the result did not equal my expectations. The party, as reduced, numbered about 20 men, all told. These with the necessary instruments, rods, chains, &c., and with four skiffs, made the surveys below Le Claire.

We arrived with this party at Burlington, Iowa, October 21, where a railroad bridge had been authorized by Congress. Our survey commenced about 1 mile above the town and extended to a point about 1½ miles below it, a total distance of about 4 miles, covering every available site for a bridge that would give the Missouri River Railroad connection to the east. Here good discharge and current observations were made. This survey was finished October 24.

From Burlington the party rowed down to Keokuk, Iowa, a distance of 49 miles, in the skiffs, arriving there on the 26th. Having a few hours before the steamboat left for Quincy, we made a survey of the river in the vicinity of Keokuk, running about 2 miles along the river, where a railroad bridge had been authorized by Congress. Time being important, we trusted to the notes of General Wilson's survey of the rapids, designed by him to furnish data for a plan of improvement. We left this place on the evening of the 26th, for Quincy, Ill., on one of the regular steamboats plying between Keokuk and Saint Louis.

At Quincy surveys and preparations had been made to commence the building of the railroad bridge authorized by Congress, but the exact location had not been fixed upon, or at least not made public. Borings had been made on different lines above the town and opposite the lower part of it. The survey was therefore commenced well up the river, and run down below the lowest site deemed practicable for a bridge, that would be accessible, a total distance of 3½ miles. The islands and sloughs were meandered, and numerous soundings were made in the main channel and island chutes. Observations for the direction of the current were made at the proposed sites above the town, and the bars in that part of the river were located. No levels were run at this place, the leveler being employed in meandering islands, locating bars, &c. The *water-surface* was referred to the city levels, the datum-plane of which

was said to be the lowest water. The water-surface at the time, referred to this, was 2.14 feet.

The party then went in the skiffs to Hannibal, Mo., where Congress had authorized another railroad bridge. The survey at this latter place was commenced about one mile above the town and extended about one mile below it, a total distance of three miles. It occupied us on November 1 and 2. The survey here included the usual transit lines on each bank of the river, the meandering of the islands, the taking of levels and soundings for the whole distance. There were also made a full set of observations for the direction of the current in front of the town, and observations for the discharge of the river. A shoal injurious to navigation, near the landing at the upper end of the town, was located by triangulation.

Hannibal was the last point on the river between Saint Paul, Minn., and Saint Louis, Mo., at which Congress had authorized, or any one had proposed to build, a bridge.

Having finished the survey here, the whole party was discharged, except the assistants, who were directed to proceed to Saint Paul, Minn., to prepare the maps.

In addition to the work of this main party under my supervision, Mr. Frank Cook, civil engineer, had, in October, made a survey of the Mississippi River from the bridge above Saint Anthony Falls to Meeker's Island, 2.62 miles below the falls. This survey included the falls, and the dams, flumes, mills, &c., near them, with a line of levels from the bridge to Meeker's Island. Mr. Cook also made a reconnaissance of the river from Meeker's Island to Fort Snelling.

The preliminary report on all these surveys was submitted by me January 21, 1867, and is published as House Ex. Doc. No. 58, Thirty-ninth Congress, second session.

The following table shows the extent and location of the surveys made between September 13 and November 3, 1866:

Locality.	Date.	Left bank, miles run.	Right bank, miles run.	Islands, bars, &c., miles run.	Levels, miles run.	Sounding-lines, total length.	Number of sounding-lines across river and chutes.
	1866.						
Falls of Saint Anthony to Meeker's Island		2.75	2.75	.....	3.00	.....	.....
Fort Snelling to Red Rock	Sept. 13 to Sept. 24.	13.5	13.75	4.00	16.00	31.25	200
Hastings, Minn., to Prescott, Wis	Sept. 24 and 25	4.5	2.00	2.50	6.00	9.00	65
Head of Lake Pepin	Sept. 26	1.50	2.25	3.00	0.50	6.75	44
Mouth of Chippewa River to Alma, Wis	Sept. 27 to Oct. 1	9.00	12.75	2.00	12.75	23.75	120
Minneiska and Chimney Rock	Oct. 1 and 2	1.50	1.50	0.50	.....	3.50	17
Rolling Stone	Oct. 2	1.00	1.00	.....	.....	2.00	15
Winona, Minn	Oct. 3 and 4	4.00	3.00	1.75	3.00	8.75	50
La Crosse, Wis	Oct. 5–7	5.00	4.00	2.00	6.00	11.00	70
Coon Slough and Bad Axe	Oct. 7	1.00	1.00	0.50	.....	2.50	6
Prairie du Chien, Wis	Oct. 8–10	7.00	7.00	9.00	7.00	23.00	110
Guttenberg, Iowa, and Cassville, Wis	Oct. 11	1.00	1.00	1.50	.....	3.50	20
Dunleith, Ill., and Dubuque, Iowa	Oct. 12–14	5.50	3.50	.....	4.00	9.00	100
Fulton, Ill., to Clinton, Iowa	Oct. 15–17	3.25	2.75	2.25	2.00	8.25	150
Burlington, Iowa	Oct. 22–24	3.25	4.00	.....	4.00	7.25	100
Keokuk, Iowa	Oct. 26	2.00	1.25	.....	1.25	3.25	9
Quincy, Ill	Oct. 27–30	3.5	3.5	7.25	.....	14.25	70
Hannibal, Mo	Oct. 30, Nov. 3	3.25	3.5	1.25	3.00	8.00	80
Totals		72.50	70.50	37.50	68.50	177.00	1,226

It may be said of these surveys, that while they have no claim to the refined accuracy of geodetic work, they are as good as good plane-table surveys. The party was large, and composed of men of experience in surveying, and possessed of much activity, and everything thought to have a bearing upon the question of bridging, or that gave information about the river was searched for and obtained if possible. This remark is necessary, because some persons have thought the field was gone over too rapidly to be thorough, but this was not the case. Our subsequent experience enabled us to extend our work, but showed no fault in the conclusions from the survey.

The only portions previously surveyed by engineers with proper means were in the neighborhood of Saint Louis Harbor, at the Des Moines Rapids, and Rock Island Rapids, and a small part of the river near Dubuque. No lines of levels had determined the slope of the river surface, nor had gauge observations satisfactorily determined the range of surface from low to high water, and the average duration of different stages, except at Saint Louis and Rock Island.

The length of the river between Saint Louis and Saint Paul is about 790 miles as navigated by steamboats. The information previously obtained about this portion of the river was nearly all of the kind obtained by the United States land-surveys. These surveys were made on the two sides of the river from different base-lines, and seldom connected across by triangulation or other measurement. Many islands were not included in these surveys at all. Their imperfections were not appreciated by us at first, and at considerable effort and expense we had copies made from the Land Office plats along both banks of the river.

Letters were also written to all parties known to be interested in building bridges, and to all the principal steamboat companies, and conversations held with every one who would give facts or views in regard to the matter. In this way a number of town plats were secured that aided us somewhat in connecting our surveys with the United States land-surveys.

We thus found ourselves possessed of a large amount of crude topographical information procured by ourselves and others, some of it of recent date, and some of it, in the lower part of the Mississippi, of many years back, specially valuable as enabling us to compare the subsequent changes.

Mapping surveys made in 1866.—After the completion of the field-work, in 1866, the force of assistants was reduced to four—H. C. Long, J. P. Cotton, C. H. Conwell, and Henry Custer. This was made necessary by reason of the small amount of money available for this work. These assistants were employed in preparing the maps of the surveys, working up the notes, and in assisting in the preparation of estimates and reports.

The maps of the surveys were made on a scale of 200 feet to the inch, on manilla paper. Tracings were made of such as were submitted to the department. Sketches of particular localities were reduced to scale of 2 inches to 1 mile, to accompany the preliminary report upon all of the work of 1866 except the bridge investigation dated January 21, 1867, printed as H. Ex. Doc. No. 58, Thirty-ninth Congress, second session. On the 31st of January, 1867, a map on a scale of 100 feet to the inch was sent to the Chief of Engineers, showing location, direction of current, objectionable features, &c., of the railroad-bridge at Clinton, Iowa. On the 4th of February I was called before the Committee on Post-Offices and Post-Roads, Hon. Alexander Ramsey, chairman, and

gave my views in reference to the Clinton bridge, the substance of which is included in the special part of Chapter V relating to this bridge.

The attempt was made to construct a map of the whole river on a scale of 2 inches to the mile from the data on hand, but it was found so incomplete that the only use of it was to show how much was lacking, and what we must supply.

Surveys made in 1867.—In April and May I attended, as a member, the meeting of the Board of Engineers at Keokuk, to report upon the plan for a canal to avoid the rapids in the Mississippi just above that place. Messrs. Cotton and Conwell accompanied me here, and while performing work connected with the Board, we investigated the river phenomena, getting measures of volume, &c. The Board adjourned to Davenport, Iowa, and there we made similar investigations and measurements, and some additional ones at the Clinton bridge, 34 miles above Davenport. The surveys at Davenport, though limited in extent, proved of value afterward when the construction of the Rock Island bridge was begun in 1869.

On the adjournment of the Board in May, 1867, I proceeded with Messrs. Cotton and Conwell to Saint Louis. Mr. Cotton set out from this place to supply connections with the United States land-surveys, and get such other information as it was practicable to obtain above that city as far as Keokuk. Mr. Conwell went below as far as the mouth of the Ohio, for the same purpose. The high water greatly circumscribed their operations, though valuable results were obtained.

Accompanied by Maj. H. C. Long, civil engineer, I proceeded to examine the wrecking-boats and other vessels that might aid us in improving the Upper Mississippi, and in doing this, went also to Louisville and Cincinnati. At this last place we saw the suspension-bridge, just finished, a monument to the capacity of engineering skill to furnish ample means of crossing a great river without obstructing its navigation.

We all arrived back at Saint Paul about the second week in June, and set about measuring the river volume and preparing to renew our surveys on the Upper Mississippi, and to begin an accurate survey of the Wisconsin River below Portage. The river at that time was too high to make surveys of the low water river, but presented a favorable opportunity to get its volume in flood stages. Preparations were immediately begun and the work of measuring the volume commenced.

To get at the amount from the Mississippi and Minnesota, a base-line was selected above Minneapolis for the Mississippi, and one above the railroad bridge on the Minnesota, and one at Saint Paul as a check on the other two. Surveys of a portion of the river immediately above and below the discharge sections were made. As it was desirable to make observations at all three places on the same day when practicable, the base near Minneapolis was abandoned, and one selected near Fort Snelling immediately above the mouth of the Minnesota River. These observations were continued with but few interruptions until the closing of the river by ice. The manner of conducting these observations and results obtained will form part of a report on improving the navigation between the Falls of Saint Anthony and Rock Island Rapids.

During July, August, and September, a quarter-boat for lodging a surveying party was built at Saint Anthony under direction of C. H. Conwell, civil engineer. This boat was 80 feet in length, and 18 feet wide, fitted up to accommodate a party of about 40 men. This boat was not as large by one-half as she should have been for comfort and convenience.

During the latter part of August and the first part of September the river between Meeker's Island and Fort Snelling was surveyed. This was done while the party were regularly making observations for discharge of the Minnesota River, the Mississippi River at Fort Snelling (above the mouth of the Minnesota) and at Saint Paul.

In the flood of July, 1867, the channels about Pike Island underwent great changes. The channel between it and Fort Snelling was nearly filled up, while the other, north of the island, was enlarged. In the latter part of September these channels were resurveyed, the shores meandered, and soundings taken in all of the channels. These soundings were all located by measured angles from each end of a measured base on the shore. The water's surface was referred to permanent bench-marks in the vicinity, and the gauge-reading at Saint Paul noted. These soundings give accurately the condition of the channel at that time.

In the latter part of September the river fell within its banks. Mr. Cotton was then directed to organize a party for continuing the surveys commenced last season. This party consisted of J. P. Cotton, in charge; J. A. Craik and Job Voak, civil engineers, transitmen; H. P. Farrar, civil engineer, leveler; A. M. Scott, civil engineer, compassman; and H. D. Van Pelt, recorder of soundings; with chainmen, rodmen, axmen, boatmen, and cooks, the party numbering 38 men all told.

Work was commenced near Pig's Eye Island, 3 miles below Saint Paul. This portion of the river had been surveyed in 1866, but in the mean time the bar at the head of the island had been troublesome, and had been reported to be composed in part of loose rocks or bowlders. The survey was made to settle this question, and to see what changes had taken place in the bars of this part of the river. The manner of conducting surveys this year was much the same as that followed by the party of 1866, a transit line being run on each bank, a compass line on the islands, a level line on one bank, and lines of soundings as often as every 500 feet.

The transit lines were run by deflecting from the back sight at each change in the line, this deflection being noted and at the same time the magnetic bearing. The first deflection at the end of the first course was subtracted from or added to the magnetic bearing of the first course, and entered in a column in the note-book marked "corrected course" directly opposite the magnetic bearing of the course. At the next angle point the deflection was noted in its proper column "right" or "left," the "corrected course" of new line figured, and the magnetic bearing of it recorded in its column. The sample below illustrates the way the notes were kept:

Station.	Right deflection.	Left deflection.	Corrected course.	Magnetic course.
5	.....	.....	.....	.....
+.50	.....	7° 18′	N. 23° 20′ E.	N. 23° 15′ E.
.4	.....	.....	.....	.....
.3	.....	.....	.....	.....
+.27	3° 23′	.....	N. 30° 38′ E.	N. 30° 45′ E.
2	.....	.....	.....	.....
1	.....	.....	.....	.....
0	.....	.....	.....	N. 27° 15′ E.

By this method any error in reading or recording the deflection angle would be likely to be discovered in time to correct it, and cases of local magnetic disturbance would be detected. This method of keeping notes will generally prevent a careful engineer from making great errors in recording, and enable him to detect at the time an error in reading.

These transit lines were connected as often as each half mile by trian-

gulation, each transitman setting up a signal at a station on his line which the other was instructed to locate by taking angles to from two or more angle points on his line.

The transitmen were charged with setting blazed stakes or other signals at the water's edge at each 500 feet of their line, or oftener in special localities, and note the station and distance from the line in their notebook; also write the number of the station on the stake or signal. The signals set by either transitman were marked with his initials, and all set up on a continuous survey were numbered serially. Each transitman was furnished with a boat and boatmen whose duties were to transfer the party from the quarter-boat to the work and back, to carry them across sloughs, and to set up signals on the head and foot of islands and sand bars.

The compassman, in meandering the islands, commenced at the signal set up by the transitman, or, in case the transit lines had not reached this part of the river, he set up such signals at his starting point, and prominent points along the line to be located by them.

The assistant in charge of the sounding party was instructed to sound between all the sounding stakes, and always to run a line of soundings across the head and foot of each island, chute, bayou, or slough. A line of levels was run on one bank, and the height of the banks of main shore and islands noted. Cross-sections of the valley were run as frequently as could be done, and keep the main line along with general survey of the river. The assistant in charge, Mr. Cotton, was continually employed in the field directing the parties, and especially looking after the hydrography of the river, staking out and locating submerged bars, noting the prominent points supposed to direct the currents, and sketching such sloughs and bayous as were not deemed of sufficient importance to require meandering.

For the first two weeks after taking the field the lines run were roughly plotted in the evening to see that each principal of party was performing the duties required of him in such manner as would insure satisfactory results in the map of the survey. The plotting of the notes brought forcibly to the minds of these assistants who had heretofore been employed on railroad surveys only, the importance of particular attention to details in their topographical notes, such as the accurate delineation of all rocky spits that might act as wing-dams in their influence upon direction of the current at certain stages; the location of small tributaries which, in floods, might bring in large quantities of sand, gravel, &c. The cross-section of these, at the time of survey and when bank-full, should always be noted.

Having made the survey in the vicinity of Pig's Eye Island, as previously stated, the boat was allowed to float down to Red Rock, the termination of the continuous survey from Fort Snelling made in 1866, where the regular survey was commenced on the 3d of October, the gauge at Saint Paul reading 4.2 feet. From this point to Hastings, Minn., a continuous survey of the main river was made; all of the principal islands were meandered; a level line run, and three partial cross-sections of the valley made; observations for discharge of the principal sloughs were made, and a set of observations for volume of the whole river at Hastings.

The quarter-boat was managed by two boatmen. As soon as the parties had gone out to work in the morning, if the wind did not blow, they pushed the boat out into the current and let her float down river about as far as the parties would be likely to get by night. This was always done early in the morning because at that time it was usually calm, while

later in the day the wind generally blew from the south so strong as to make the moving of the boat an impossibility without motive power other than the current.

The survey to Hastings was completed on the 14th of October, and on the 15th the quarter-boat was taken in tow by the United States steamer Montana and left at the mouth of the Cannon River, where a survey of three miles of river was made, which included the forking of the river into two of the three channels by which it enters Lake Pepin.

On the 17th October, the quarter-boat was towed to Wabasha by the *Montana*, where the survey was again commenced.

This embraced an instrumental survey of the larger and a reconnaissance of the smaller sloughs in the delta of the Chippewa River, extending up this river 14½ miles to where the river is all in one channel. The Mississippi River survey was repeated over parts surveyed in 1866, for the sake of noting changes, and it was continued to Winona, Minn., a distance of about 35 miles along the valley (a much greater length measured along the river). It embraced the whole valley from bluff to bluff, often 5 miles in width. All of the sloughs that are ever navigated by small steamboats or rafts were meandered and sounded out, and most of those which were too small for either were sketched.

The surveying of the sloughs and side-channels was done at a great outlay of time and labor, as some of them were as much as 5 miles in length, requiring a journey by boats of this distance morning and evening when at work near the middle of the longest of them. While surveying this part of the river it became necessary to organize extra sounding parties, as it was impossible for one party to sound out all of the channels and keep along with the other parties. In surveying the 10 miles of river immediately below Alma two full parties for sounding were constantly employed. This was frequently done, the leveller and his party, or one of the transit parties, making a second sounding party. Throughout the whole survey the assistants were called upon for any duty connected with the work, such as locating submerged bars, making observations for discharge, making cross-sections of the valley, taking heights of bluffs, &c. The survey to Winona was finished on the 8th day of November, connecting with the survey made at that place in 1866.

The next point at which it was deemed desirable to have detailed surveys was at Coon Slough, some 35 miles below Winona, measured along the valley. We tried to get one of the steamers to tow the quarter-boat down, but it being near the close of the season, and plenty of freight offering, none were found willing to be bothered with such a tow. After waiting two days trying to get towed, Mr. Cotton concluded to try to float down. As the wind almost invariably blows up stream during the day at this season, it had to be done by night if at all. The party was accordingly divided into three reliefs, two boats were manned by a relief. and with a line to the quarter-boat, started on the evening of November 11, as soon as the wind went down sufficiently to permit it.

This was continued by each relief working two hours and resting four, through the night. At the upper mouth of Black River they were met by the south wind, which prevented further progress. The day was spent in making a survey of 4½ miles of the river at this point. As soon as the wind went down in the evening the boat was again started on her journey, this time by "cordelling," when the nature of the shore would permit, and by towing with skiffs when the shore was not suitable for "cordelling." Brownsville, at the head of Coon Slough and

Raft Channel, was reached on the following day about noon, and the survey commenced in the afternoon of November 13.

The two principal channels were surveyed, and all of the smaller ones either surveyed or sketched. The survey of this section to Genoa, or Bad Axe, a distance of about 13 miles, was completed on the 19th day of November, and the boat towed to Lansing in that night by means of skiffs, in the manner described above. A survey of 1½ miles was made at this point, when, on account of the lateness of the season, it was deemed best to discharge the parties and lay the boat up for the winter. This was accordingly done on the 22d day of November, the party having been in the field since the 1st of October. During this time not a day was lost on account of bad weather, field-work being carried on every day except when moving from point to point.

The surveying party, under direction of Maj. C. R. Suter, Corps of Engineers, on the Wisconsin River, on reaching the Mississippi were directed to drop down to Clayton and make a survey of the Mississippi, so as to include the two parts known as the Cassville and Guttenberg channels, and their connections. This survey was made between the dates of October 7 and 12, and embraced a distance of 9½ miles measured along the valley. This surveying party was conducted in the same manner as that on the Mississippi already described.

In addition to these surveys, special examinations were made by myself and assistants, Conwell and Brunson, in the delta of the Chippewa; in the lower part of the Cannon River; in various sloughs and chutes in parts of the river not embraced in the detailed surveys, and observations for volume of the Mississippi River and sloughs, and of some of the tributaries.

The following table exhibits the results in miles run, &c., of the surveys of this season:

Location.	Date.		Transit.	Compass.	Level.	Miles of river.
	From—	To—				
Pig's Eye	Oct. 2	Oct. 2	6	.....	.....	2
Red Rock to Hastings	Oct. 3	Oct. 15	30¾	16	20	17
Mouth of Cannon River	Oct. 17	Oct. 17	3¾	2	3	2
Alma	Oct. 18	Nov. 8	77¼	35¼	46	36
Black River	Nov. 12	Nov. 12	4	2¼	.....	4
Coon Slough	Nov. 13	Nov. 19	21¼	11¼	16¼	10
Lansing	Nov. 22	Nov. 22	1¼	.....	¼	1¼
Meeker's Island to mouth of Minnesota River	Aug. 26	Sept. 12	9	8¼	10	8
Guttenberg and Cassville	Oct. 8	Oct. 12	20½	18	9½	9½
Total	.....	.....	174	93¼	105½	90

In June, 1868, I was directed to examine the railroad bridge across the Ohio River at Steubenville, Ohio. My report upon the result of this examination was submitted June 29, 1868. With it was a

Draught of provisions required to secure to navigation the full benefit of the passage-way through bridges across navigable streams, the least width of which passage-way is fixed by law,

and an estimate of cost of bridge 1,700 feet long,

With continuous spans, one of them 500 feet in the clear, two of them 300 feet in the clear.

This report, draught of law, and estimate were published as part of report of Senate Committee No. 168, Fortieth Congress, second session.

In the succeeding annual report of the operations for the fiscal year

ending June 30, 1868, the results of the surveys are partially given and a statement of the progress made in completing the maps.

Surveys in 1868.—In October, 1868, Mr. Cotton, who had been employed with assistants since the close of last season in working up the notes of his work in 1867, was directed to organize a party and make special surveys at points along the river where surveys had been made before to ascertain what changes, if any, had taken place, and also at bridges and proposed sites for bridges.

The party as made up consisted of J. P. Cotton, civil engineer, W. Weston, civil engineer, A. M. Scott, civil engineer, and 2 rodmen, 4 boatmen, and one cook. They were provided with 3 skiffs and 3 wall-tents.

Work was commenced in the vicinity of the mouth of the Minnesota on the 12th day of October. The volume of the Minnesota and of the Mississippi above and below its mouth was measured. A full set of current observations at the bridge of the Milwaukee and Saint Paul Railway over the Minnesota, and soundings above and below it, were made.

In making surveys and observations for direction of current, either at bridges or otherwise, this season, the following method was pursued. A base line as long as the location would admit was selected, and its length carefully measured. A transit was set up at each end and the angles to all prominent points in the vicinity measured; if at a bridge, a rodman was directed to hold a flag-staff at the middle of each pier, the angle to this staff being simultaneously measured from each end of the base by the transitmen. When the weather was favorable the party proceeded at once on their arrival at a bridge to make observations for direction of current so that no delay should occur on account of windy weather. All soundings made during this survey were located by triangulation. The level of the water's surface was referred to permanent marks so that comparisons can be made in the future.

The piers of the bridges, size, height, and shape were carefully measured, and also the principal parts of the superstructure.

Having finished the examinations at this point, tents were struck and the party proceeded to the Milwaukee and Saint Paul bridge (railway) over the Mississippi 2 miles above Saint Paul. Here they went into camp and spent days in sounding, making current observations, and measuring the piers and running levels to enable them to construct a cross-section along the line of the axis of the bridge.

The next examination was at the Saint Paul highway bridge. Here current observations were made.

From this point to Wabasha, Minn., the party with skiffs, tents, instruments, &c., went by steamer.

From Wabasha to Alma, a distance of 3½ miles, soundings were taken on all of the bars shown by survey of 1866 or 1867, and on those where navigation had been obstructed during the season of 1868. Special pains were taken to locate the crossings on bars where the scraper dredge-boats had been employed during the season. The surface of the water was referred to the bench-marks of 1867 and observations made in all of the island chutes for discharge as nearly as practicable on the sections used in 1867 for this purpose.

From Alma the party went in skiffs to Rolling Stone Bars (about 3 miles above Fountain City). Here a survey of the bars at the head of Rolling Stone Slough and Horse Shoe Bend was made; the crest lines carefully defined by a line of soundings along them, and soundings

above and below them. Observations were made for discharge of all the side channels.

The next point at which examinations and surveys were made was at Winona, Minn., where preparations were being made to erect a railway bridge. The survey here consisted in locating soundings in all of the channels, observations for volume of the east channel where the bridge had been located, and a cross-section of the intervening island, and of the main or west channel.

The next point at which it was proposed to make surveys was at Dubuque, Iowa, so far below that it was economy to go by steamer. Accordingly, skiffs, tents, and party were transferred by steamer, reaching Dubuque on the 28th day of October, when tents were pitched, and the survey commenced. This survey embraced, in addition to the current observations, soundings, and measurements at and about the railway-bridge in process of construction at this point, and a survey of the harbor of Dubuque, which had been for several years becoming more difficult of access in low water, by reason of a sand-bar extending along the whole front of the town. This survey was completed November 1. The rest of the surveys to be made being at or near towns, it was deemed cheaper and more expeditious to send the tents back to Saint Paul, and find board for the party at points where examinations were to be made.

The next point where examinations were made was the Clinton Bridge. This had been surveyed in 1866 and 1867, so that it was not deemed necessary to do more than make a few observations for direction of current, and a survey of that part of the bridge over the east channel which was being rebuilt. The survey at this place was completed on November 6.

The next point at which surveys were required was at Rock Island, to which place the party went by steamer. Here a survey of the bridge and current observations above and below were made. The work was completed on the 11th day of November.

From this point the party went by steamer to Burlington, Iowa, and made a survey of the railroad bridge and a full set of current-observations. This bridge had been built since the survey of 1866. A full survey of the bridge and of the river above and below it was made; also, a complete set of current-observations above and below the bridge. The survey at this point was completed on the 14th of November, and the party went to Fort Madison, Iowa, in skiffs that evening.

On the following morning they went to Keokuk, Iowa, and took steamer to Quincy Ill. A survey was made of the railroad bridge just completed at this place, and a full set of current observations taken above and below the bridge.

From this place the party, with skiffs, &c., went by steamer to Alton, Ill., reaching there on the 19th instant. The survey was commenced on the following morning at Hop Hollow, about two miles above Alton. From this point a line was run on one bank and part of the distance on both down to and including the mouth of the Missouri River, connecting there with the survey made by Col. W. E. Merrill, Corps of Engineers, for Saint Louis Harbor. Soundings were located throughout the whole of this distance of 7½ miles. Observations were made for the discharge of the main river, and of the sloughs back of the sand-bar opposite Alton and west of Ellis Island. Soundings were also made in these sloughs with special reference to estimating the cost of closing one of them as a means of improving the navigation in the main channel of the river along the levee front of Alton.

At the mouth of the Missouri River, special observations were made

for the direction of current where the two rivers unite. The great length of base line used here made the *calling* of "time" impracticable.

To insure as near simultaneous reading of the angle as possible, the time-keeper was stationed close to one of the observers with a flag. Another man was stationed by the other observer, whose duty it was to watch the motions of the time-keeper, and inform the observer. When a float was started from the boat, the time-keeper called attention to it by raising his flag 5 seconds before the even half-minute; at the even half-minute, he dropped the flag and called "*time*" to the observer near him. These motions would be seen and communicated by the attendant to the observer at the other end of the base. A set of signals were agreed upon between the party in the boats and the observers before commencing, so that all movements by either party were readily communicated to the others, thus preventing mistakes and loss of time; an important item, when working in a river where the current ran 4 miles per hour and the points of observation three-fourths mile apart.

This survey was completed on the 5th day of December, the boats stored at Alton, and the party disbanded the assistants returning to Saint Paul with instruments and note-books, to prepare the maps and diagrams.

Late in the winter, after much delay, a current meter was received at Saint Paul, and some interesting velocity-observations under the ice at different depths were obtained.

In October of this year, I was appointed member of a special commission, under the Interior Department, to report upon the condition of the Pacific Railroads. This duty was finally made to embrace all Pacific Railroads and branches, and occupied all my time until July, 1869.

Surveys in 1869.—In July, 1869, I was ordered to proceed to Rock Island, Ill., and relieve Col. T. J. Rodman, United States Ordnance Corps, of the charge of the construction of the new government bridge to connect Rock Island with Davenport, Iowa.

Before fixing upon the final plan and location, it was necessary to have a much more extensive map of soundings and current-observations for direction and velocity than had as yet been made, and I directed Mr. Cotton to make these surveys. The quarter-boat used on previous surveys was towed down and a party put on board, and the work commenced on the 30th of July.

The river at the time was quite high and the current so strong that a boat could not be rowed against it. To sound in a desired locality, it was necessary to go with the boat some distance above, keeping near the shore, and then reach the spot by steering out obliquely with the current. Having arrived at a point in the stream directly above the desired location, the boat was anchored, and then allowed to drop down by paying out the anchor-line. In this way the whole river was sounded over for a distance of several hundred feet above and below the proposed bridge location. The bottom of the river being rock, with occasional "pots" or holes in it, a great many soundings were necessary to properly delineate it. Within a distance of one-half mile, upwards of 8,000 soundings were taken before a satisfactory contour-map of the bottom could be made. Several days were also spent in making current-observations.

Upon the completion of this survey and map, Mr. Cotton, with assistants H. A. Bentley and L. S. Chase, was directed to make observations at the *Burlington*, *Keokuk*, *Quincy*, and *Dubuque Bridges*, the object being to get the direction of the current at the high stage of water then pre-

vailing, and which opportunity had not occurred before. The annual report of the Chief of Engineers of our operations during the fiscal year ending June 30, 1869, gives the condition of the Mississippi maps and data at that date.

Circumstances under which maps and report were prepared.—Much progress was made during the winter of 1869–'70 in plotting the surveys in pencil, but ill health prevented my doing any hard work after the 1st of January.

During the month of February, 1870, the stations of a number of officers of the Engineer Corps were changed by orders, and I was assigned to the charge of the Lake Surveys, one of the duties of the highest honor and importance under our management. But at the time my health was so enfeebled that, at my own request, I was relieved from it. As the same orders had assigned Colonel Macomb to the charge of my duties, I was given the station at Newport, R. I. It should be noted here that although I had made considerable surveys and measurements on the Mississippi, I had no opportunity to complete the report. From October, 1868 to June, 1869, I had been away on the Pacific Railroad; from June to October, I was closely occupied in starting the work on the Rock Island Bridge; during October and November, I was upon the Wisconsin River projects; and in December, in arranging for work upon the large amount of field work and notes that were to be elaborated. Among other matters not named was a detailed survey of the battle-field of Gettysburg. These things are given fully in the first chapter of my report on the Wisconsin River.

I was authorized to take all my unfinished work on the maps and reports with me to Newport, and complete them there.

In the summer of 1870 I had all I could do in performing the duties of my new station.

On October 18, 1870, I was appointed a member of a Board of Engineers to examine the bridges on the Ohio River in accordance with section 5 of the act making appropriations for the improvement of rivers and harbors, approved July 11, 1870. The partial reports of this Board were made December 12, 1870, and February 7, 1871, and the final report April 19, 1871, all of which were printed in the Chief of Engineers' Report for 1871, pp. 397 to 457 inclusive.

By Special Orders No. 106, dated Headquarters Corps of Engineers, September 29, 1870, a Board of Engineers, of which I was the senior member, was ordered to convene at Buffalo, N. Y., to examine the plan and location of the international bridge over the Niagara River at that place. The report of this Board was published in Chief of Engineers' Report for 1871, pp. 219, 220, 221.

On the completion of the duties on these Boards in the spring of 1871, the very large amount of local work at the Newport district required undivided attention during the whole outdoor working season.

I was again a member of an Engineer Board, reconvened by special Orders No. 108, Headquarters Corps of Engineers, dated August 3, 1871, to consider the plans for the modification of the Cincinnati and Newport bridge, as submitted by Thomas A. Scott, esq., president of the Pennsylvania Railroad Company.

In August, 1871, the project of bridging the Missouri at Saint Joseph, prepared by the chief engineer, Mr. E. D. Mason, was submitted to me for remarks. My reply was dated August 25, 1871. But we got at work with a very large office force in the autumn and winter, and by February had essentially completed all the original maps and the compilation of the map on a scale of two inches to the mile, and sent

tracings of them to Washington; but though many parts of the several reports were prepared, there was not time enough to complete any final report. I had to at once attend as a member of a Board on the harbor of Saint Louis (see Annual Report for 1872); and another month was used up as a witness against the contractor for the Rock Island bridge masonry.

March 27, 1872, I made a report upon Senate bill 845, of Congress then in session, authorizing an additional bridge across the Mississippi River at Quincy, Ill.

June 29, 1872, I submitted a report upon the bridging of the Mississippi River at La Crosse, Wis.—(See La Crosse bridge, in Chapter III.)

Duties at Newport occupied all the outdoor working season. The winter of 1872-'73 was passed in study of works on river and canal improvements and in arranging and elaborating the data from the Mississippi surveys for the final reports. The general map on scale of six miles to the inch was partially finished.

January 16, 1873, Senate bill 1302, authorizing the construction of a bridge across the Mississippi River at Saint Louis, was sent to me for report with recommendations and suggestions. My report upon this, dated January 21, was submitted.

January 25, 1873, a substitute for Senate bill 1302 was sent me for report. My report upon this was transmitted January 28, 1873.

May 21, 1873, the plan of a proposed bridge across the Mississippi River at Louisiana, Mo., authorized by act approved March 3, 1871, was submitted to me for investigation and report. My report was forwarded under date of May 31, 1873.

During 1873 I was president of a Board of Engineers to report upon bridging the navigable channels between Lakes Huron and Michigan (see Annual report for 1874, pp. 947-1051)|; also member of a Board of Engineers to report upon the obstruction to navigation caused by the bridge at Saint Louis (see Chapter III); also member of the Board on the Fort Saint Philip Canal project.

The first part of 1874 was a very busy period at my Newport station. In June, 1874, I was made president of the commission on the protection of the alluvial regions of the Mississippi. This commission exacted a good deal of hard labor, but the final report on the Minnesota River was completed and the last of the Mississippi bridge surveys was finished and copies sent to Washington.

No other work upon the Mississippi River bridges was done until after the rendition of my final report on the Wisconsin River, November 26, 1875, and the attempt was then made in the beginning of 1876 to complete the final report on bridges, but there had been so many of the bridges completed since of surveys in 1869 that it was thought desirable to obtain authority and money to make surveys of them in the season of 1876. These were given by the Chief of Engineers out of available funds, and surveys were accordingly made of the bridges at Hastings, Winona, La Crosse, Prairie du Chien, Keokuk, Hannibal, and Louisiana. The maps and tracings were completed in January, 1877.

During the season of 1876 I was also made a member of the Board o Engineers to consider the question of placing sheer-booms at the piers of the bridges on the Mississippi to facilitate the passage of rafts. All the maps obtained by me were placed at the use of the Board, which completed its report February 2, 1877. (See Annual Report for 1877.)

After the duty on this Board was over, the preparation of the maps for publication was begun and continued until the outdoor work stopped us. In the autumn the opportunity was presented of taking up this

final report with a prospect of finishing it. There was only one interruption given, and that was in the reconvening of the Board of Engineers on the Ohio River bridges at Evansville, which caused about a month's delay. The office-work on the final report has been pursued without a day's intermission (when not interrupted by local duties) through the winter and down to the date transmitting it.

While conducting the surveys and other work in a field as little developed as this was, we gathered everything we could, so that if it could aid us in any way, directly or indirectly, we might have it at our command. While this was going on, we had necessarily to keep our office maps, &c., in an unfinished state, so that they might be open at all times to additions and revisions; but, at the same time, the field-work was as rapidly as possible worked up according to its nature and plotted on maps or assembled in tabular form. Thus we passed out of that stage when reference to note-books was necessary, while as yet the maps designed for final presentation were left in pencil or were finished as special representatives. A great deal of the practical results were thus at once available for immediate use on the improvements and questions concerning bridging.

The maps constructed were on several scales and on separate sheets, of which the following is a detailed description:

LIST AND DESCRIPTION OF ORIGINAL MAPS.

The maps of the river constructed from our surveys are on several scales and on separate sheets. That portion of the river from the level above the Falls of Saint Anthony to the outlet of Lake Saint Croix was all surveyed, and has been mapped on ten successive sheets averaging in length about 10 feet each, on a scale of 200 feet to the inch.

Portions of the river were more than once surveyed to measure changes going on, and at such places there is more than one map to be duly described. On these maps the transit lines and triangulation lines are shown; places of making velocity observations and volume are given; sections along and across the river and valley, topography, depths of water, levels of water surface and bank, connections with United States land surveys, and all the information that could be obtained, is shown.

The following is a detailed description of these maps, viz:

Sheet No. 1 begins 2½ miles above the Falls of Saint Anthony and extends down about 6½ miles.

Most of the survey was made in 1867. The part from the falls to Meeker's Island, about 2¾ miles, as first surveyed, was sent to Washington with the report of my assistant, Mr. Frank Cook, civil engineer, dated December 31, 1866, on a scale of 200 feet to an inch. It was made with a view to an improvement by dam and lock at Meeker's Island.

Subsequently, in 1869, some additional soundings, not shown on Cook's map, were made, of which a report appears in the Annual Report of the Chief of Engineers, 1870, p. 275. Tracing of this sheet sent to the Chief of Engineers February 14, 1872.

Sheet No. 2 extends down to Fort Snelling, including the junction of the Minnehaha, a distance of about 4 miles along the river, surveyed in 1867. A copy of this map from Minnehaha Creek down to Fort Snelling, a distance of about 2 miles, was furnished Lieut. Thomas Turtle, Corps of Engineers, in the spring of 1870, and used by him in establishing the boundaries of the Fort Snelling reservation. The section of the river shown on the lower end of the map was much used by us in measuring

volumes of discharge in the Mississippi and Minnesota Rivers. A tracing of this map was sent to the Chief of Engineers February 14, 1872.

Sheet No. 3 extends from Fort Snelling downward about 4½ miles. This was surveyed in 1866. It shows Pike Island at its upper end, and the railroad bridge across the mouth of the Minnesota River. At its lower end is the first railroad bridge across the Mississippi. A tracing of this map was sent to the Chief of Engineers February 14, 1872. This sheet is accompanied by three other sheets, designated as No. 3′, No. 3″, No. 3‴.

No. 3′ is a map, on the same scale, of a resurvey of Pike Island, made in 1867 during the low water which succeeded the summer floods which had, for the first time on record, closed the channel between the Mississippi and the Minnesota at the west end of the island. The river opened this again in the succeeding flood. A tracing of this was sent to the Chief of Engineers March 9, 1872.

No. 3″ is a special map of the railroad draw-bridge across the mouth of the Minnesota River, on a scale of 100 feet to an inch; the vertical scale of the profile is 10 feet to an inch. It shows the observations, giving direction and velocity of current, made in 1868. Tracing of this sent to Chief of Engineers December 2, 1874.

No. 3‴ shows the railroad draw-bridge across the Mississippi, from surveys in 1868, on the same scales and in the same manner as described of No. 3″. A tracing of this was sent to the Chief of Engineers December 2, 1874. This tracing was, at my request, returned to me January 20, 1877, and additional current observations, made under direction of Maj. F. U. Farquhar, Corps of Engineers, added. This was returned to the Chief of Engineers February 23, 1877.

Sheet No. 4 includes Saint Paul, where extensive current observations were made, and the high bridge at this place; it extends 4½ miles along the river, it also includes part of Frenchman's Bar. This survey was made in 1866. Tracing of this sheet was sent to the Chief of Engineers February 14, 1872.

Sheet No. 4′ repeats the portion of the river near the bridge on a scale of 100 feet to an inch and vertical scale of profile 10 feet to an inch. Current measurements for direction and velocity are shown; also detailed drawing of a principal pier. The river section at this bridge shows changes at different dates, proving that when encroached upon in one part it enlarged at another. Tracing of Sheet No. 4′ was sent to the Chief of Engineers December 2, 1874. This tracing was, at my request, returned to me January 20, 1877, and additional current observations, made in 1876, under direction of Maj. F. U. Farquhar, Corps of Engineers, added. This was returned to the Chief of Engineers February 23, 1877.

Sheet No. 5 extends from Frenchman's Bar to Red Rock, a distance of about five miles. It was surveyed in 1866. It includes part of Frenchman's Bar, the Pig's Eye Bars, the Kaposia Bar, and Upper Red Rock Bar. A tracing of this sheet was sent to the Chief of Engineers February 14, 1872.

No. 5′ is a resurvey, made in 1867, of Lower Frenchman's, Upper and Lower Pig's Eye, and Kaposia Bars, on same scale as the other. Tracing of this was sent to the Chief of Engineers March 9, 1872.

Sheet No. 6 extends about 4½ miles along the river, and includes Lower Red Rock Bar and Newport Bar. It was surveyed in 1867. Tracing was sent to the Chief of Engineers February 14, 1872.

Sheet No. 7 extends 5 miles along the river. It includes Robinson's

Bar, Pine Bend, and nearly all of Gray Cloud Island. It was surveyed in 1867. Tracing was sent to the Chief of Engineers February 14, 1872.

Sheet No 8 extends about 5½ miles along the river, and terminates at Nininger. It shows Upper and Lower Gray Cloud Island Bars, and Upper and Lower Nininger Bars. The survey was made in 1867. A tracing was sent to the Chief of Engineers February 14, 1872. Scale of map, 200 feet to the inch.

Sheet No. 9 extends about 4½ miles along the river from Nininger to and including Hastings, Minn., where a bridge has been authorized by Congress. This survey was made in 1867. A tracing of this map was sent to the Chief of Engineers February 14, 1872. Scale of map, 200 feet to one inch.

Sheet No. 10 extends about 5 miles along the river, and includes Hastings, Minn., and Prescott, Wis., also the outlet of Lake Saint Croix. On the lower part of this sheet Prescott Island is shown; this island at time of low water, divides the river into two nearly equal channels, in which there is usually more or less trouble to navigation. It has been proposed to close one of these channels by a dam. This survey was made in 1866. A tracing of this map was sent to the Chief of Engineers February 14, 1872. Scale of map, 200 feet to one inch.

Sheet No. 10′ is a map of about 1 mile of river at Hastings, Minn., including the railway draw-bridge and approaches. It shows direction and velocity of current, general form of piers, guard-rests, trestles, &c. Tracing of this sheet was sent to the Chief of Engineers January 19, 1877. Scale of sheet, 100 feet to the inch; vertical scale of profile and section, 10 feet to the inch.

The continued river-survey breaks here.

Sheet No. 11 is on the scale of 400 feet to the inch. It is a detailed portion of the river, about 2 miles long, showing the junction of the Cannon River and the upper forking of the Mississippi into two channels, which remain distinct till they enter Lake Pepin. The survey was made in 1867. A tracing of this sheet was sent to the Chief of Engineers February 14, 1872.

Sheet No. 12 is where the south channel with its bifurcation enters Lake Pepin, near Wacouta. Some difficulty is sometimes experienced in navigating here. The space surveyed was about 2 miles. It was surveyed in 1866. A tracing was sent to the Chief of Engineers February 14, 1872. Scale of map is 400 feet to an inch.

Sheet No. 13 is from the mouth of the Chippewa River to Alma, Wis., a distance of 11 miles. This section of the river is more obstructed by sand-bars than any other below the outlet of Lake Saint Croix. It includes the bar below Read's Landing, the bars near Crat's Island, the Beef Slough Bars and Beef River Bars. The question of improving navigation in this part of the river involves all considerations relating to the improvements of rivers with movable sandy beds, so that this sheet has special interest. The survey was made in 1866. Scale of map is 400 feet to an inch.

Sheet No. 13′ is a resurvey of the same section of the river at the shoals made in 1867, with additional surveys in the delta of the Chippewa River. It also contains some special surveys, indicated in a different color, made in 1868. Tracings of Nos. 13 and 13′ were sent to the Chief of Engineers February 14, 1872. Scale, 400 feet to an inch.

Sheet No. 14 extends the map of the river 9½ miles below Alma to Minneiska. The river is divided into several channels, and sometimes has troublesome bars; but generally better navigation than exists above and below. The survey was made in 1867, and a tracing sent to the

Chief of Engineers February 14, 1872. Scale of map is 400 feet to the inch.

Sheet No. 15 exhibits about 8 miles of the river below Minneiska, embracing the bad bars just below that place, at Mount Vernon Crossing, at Chimney Rock, and at Rolling Stone. The survey was made in 1867, but the sheet shows soundings taken at Chimney Rock and Rolling Stone in 1866, and at Rolling Stone in 1868. Tracing sent to the Chief of Engineers February 14, 1872. Scale of map, 400 feet to the inch. The name Rolling Stone comes from the name of a small affluent to the Mississippi in this neighborhood.

Sheet No. 16 shows about 9 miles of river, and extends down to Winona. It contains a troublesome place known as Betsey Slough. (Betsey is a corruption of Bec scie.) There are other shoals sometimes troublesome to navigation. The main survey was made in 1867, and some additional ones about the bridge site in 1868. Tracing of this was sent to the Chief of Engineers February 14, 1872. Scale, 400 feet to the inch.

Sheet No. 16′ is a survey in the vicinity of Winona made in 1866. It covers about 3 miles and was designed to cover the probable location of the proposed bridge, not then fixed upon. Tracing was sent to the Chief of Engineers February 14, 1872. Scale, 400 feet to one inch.

Sheet No. 16″ is a map of the river at Winona, from a survey made in 1876 after the bridge was built. This map shows direction and velocity of current soundings about the bridge and the approaches to it. The continuous survey again breaks at this place.

Sheet No. 17 is a survey of Trempeleau Bar and a connection with the United States land surveys on opposite banks of the Mississippi. It shows about 1 mile of the river. Trempeleau is about 12 miles by the river below Winona. This survey was made in 1868. A tracing was sent to the Chief of Engineers February 14, 1872. Scale, 400 feet to the inch.

Sheet No. 18 is a survey near the upper mouth of Black River, including a bad low-water crossing known as "Lytle's Crossing." About 4 miles of river is shown. The survey was made in 1867. A tracing was sent to the Chief of Engineers February 14, 1872. Scale of sheet, 400 feet to the inch.

Sheet No. 19 embraces about 4 miles of the river above and below La Crosse. The survey was made in 1866 with reference to proposed bridge crossings. It contains also part of the survey made by the Milwaukee and Saint Paul Railway Company on the ice, in the winter of 1871 and 1872, to locate their proposed bridge-crossing above La Crosse. This material is shown in red. A tracing of our survey in 1866 was sent to the Chief of Engineers on February 14, 1872, and another tracing, containing the additional data obtained by the Milwaukee and Saint Paul Railroad Company, with a report in regard to the bridging of the Mississippi at La Crosse, dated June 29, 1872, was sent to the Chief of Engineers. (See Annual Report for 1873, p. 553.) Scale of sheet, 400 feet to the inch.

Sheet No. 19′ is a map of the river in the vicinity of the bridge at La Crosse, Wis., from a survey made in September, 1876. It contains current observations and soundings, and shows the approaches to the bridge and accessory works.

Sheet No. 20 shows the Mississippi from a mile above Brownsville (8 miles below La Crosse) down to Bad Axe, or Genoa, a distance of about 13 miles. This is a very interesting part of the river, containing the two nearly equal channels into which it separates, known as Coon Slough and Raft Channel. This survey was made in 1867. A tracing of this

sheet was sent to the Chief of Engineers February 14, 1872. Scale of sheet, 400 feet to the inch.

Sheet No. 21 is of a small survey made near Lansing in 1867, where the surveying-boat was laid up for the winter. This is a bad crossing-place for descending boats, as they have to run directly for the high bluffs, under which, in a dark night, the shore is undistinguishable from the water. A beacon-light was recommended for this place. A tracing of this sheet was sent to the Chief of Engineers February 14, 1872. Scale of sheet, 400 feet to the inch.

Sheet No. 22 begins at the upper end of a large island opposite Prairie du Chien, and extends down to include the mouth of the Wisconsin River, a distance of about 7 miles. The navigation in this portion of the river is excellent, and the only object of the survey was in reference to crossing the river by a bridge. The survey was made in 1866. A resurvey at the mouth of the Wisconsin, in connection with a survey of that river, was made in 1867, which can be seen on the Wisconsin River maps. A full tracing of this sheet was sent to the Chief of Engineers February 14, 1872, and of part of it on December 2, 1874, in connection with bridge maps. The scale of the sheet is 400 feet to the inch.

Sheet No. 22′ is a map of the river in the vicinity of the Ponton Railway Bridge at Prairie du Chien, Wis. It shows the general arrangement of the pontons and approaches and soundings and current-observations in both channels.

Sheet No. 23 begins a short distance below Clayton (a village 10 miles below Prairie du Chien), and embraces about 9 miles of the river. It was intended to include all of the Guttenberg and Cassville chutes, two nearly equal channels into which the river divides, causing difficult navigation in seasons of very low water; but, through a want of comprehension of the instructions, about 4 miles of the lower part of these two channels was not surveyed. Some small parts were surveyed in 1866, noted in a different color. A tracing of this sheet was sent to the Chief of Engineers February 14, 1872. Scale of sheet is 400 feet to the inch.

Sheet No. 24 represents about 3½ miles of river above and below Dubuque, surveyed in 1866, with reference to a proposed bridge-crossing. The soundings and main river-line are as then surveyed, but the sheet is made to contain side sloughs and topography the results of after surveys. A tracing was sent to the Chief of Engineers March 9, 1872. Scale of sheet, 400 feet to the inch.

Sheet No. 24′ is a resurvey of the river at Dubuque, made in 1868, after the bridge was begun and well under way. A tracing of this was sent to the Chief of Engineers February 14, 1872. Scale, 200 feet to the inch.

Sheet No. 24″ is a special representation of the bridge at Dubuque in plan and profile, with details of piers and current-measurements from survey made in 1868, with additional current-measurements at a higher stage of the river in 1869. A tracing of this was sent to the Chief of Engineers December 2, 1874. Scale of sheet, 200 feet to the inch.

Sheet No. 25 exhibits the river from Fulton and Lyons down to Beaver Island, below Clinton, a distance of about 3½ miles. My instructions required the Clinton Bridge (which the survey included), to be specially reported upon. My report was made personally to the Senate Committee on Post-Offices and Post-Roads, February 5, 1867, and a special map was, previous to this, in January, filed with the Chief of Engineers. A tracing of this map of the survey, on a scale of 400 feet to an inch, was sent to the Chief of Engineers February 14, 1872.

Sheet No. 25′ repeats the special locality of Clinton Bridge, gives the

velocity-observations made in 1866, 1867, and in 1868. It also shows present arrangement of spans, partly rebuilt in 1868. A tracing of this sheet was sent to the Chief of Engineers December 2, 1874. Scale of sheet, 400 feet to the inch.

Sheet No. 26 covers the location of the first Rock Island Bridge across the main channel of the Mississippi at Davenport and that of the new bridge. It shows the form of a pier of each bridge in profile. But comparatively few soundings are given on this sheet. It shows velocity-observations at the site of each bridge in May, 1867 and November, 1868, the water being high in 1867 and low in 1868. These observations proved of great value to us in planning the new bridge afterwards, in 1869. It shows also the location of the new bridge as made in 1869. This sheet is on a scale of 200 feet to an inch. No exact copy of this has been made. In 1869, on being put in charge of planning and building the new bridge, we made most thorough soundings, so as to completely contour the rocky river bed, and all the velocity-observations that could be of any use, and thus arranged the places and direction of the piers and spans. A map of this work, on a scale of 50 feet to the inch, was sent to the Chief of Engineers, to accompany my report of September 25, 1869. The original was turned over to Col. J. N. Macomb, United States Engineers, in May, 1870. A tracing, including all of the information, somewhat generalized and much detail omitted, was sent to the Chief of Engineers December 2, 1874. Scale, 200 feet to an inch. This tracing was, at my request, returned to me January 20, 1877, for additional current-observations made by us in October, 1876. It was returned to the Chief of Engineers February 23, 1877.

Sheet No. 27 covers about 4 miles of river in the vicinity of Burlington, Iowa. The survey was made in 1866 with reference to the proposed bridge which had been authorized by act of Congress approved July 25, 1866. A tracing of this sheet was sent to the Chief of Engineers February 14, 1872. Scale of sheet, 400 feet to the inch.

Sheet No. 27′ is a resurvey of a portion of the river, made in 1868, after the bridge was built. It shows plan and profile of the bridge and piers, and determinations of the direction and velocity of current made in 1868 at time of low water, and in 1869 at time of high water. Scale of sheet, 200 feet to the inch. A tracing of this sheet was sent to the Chief of Engineers December 2, 1874.

Sheet No. 28 covers about 1½ miles of the river at Keokuk, Iowa. This survey was made in 1866, in reference to the location of a bridge which had been authorized by act of Congress approved July 25, 1866, though the site had not been fixed upon. Scale of sheet, 400 feet to an inch. A tracing of this sheet was sent to the Chief of Engineers February 14, 1872.

Sheet No. 28′ is a resurvey of this portion of the river, with full set of current-observations, after the location of the bridge had been made and work on the piers commenced. This survey was made in October, 1869. Scale of sheet, 200 feet to an inch. A tracing of this sheet was sent to the Chief of Engineers December 2, 1874.

Sheet No. 29 extends above and below Quincy, Ill., a total distance of 3½ miles. The survey was made in 1866, and was intended to cover any location of a bridge at this place, authority having been given by act of Congress approved July 25, 1866, to build one here. A tracing of this map was sent to the Chief of Engineers February 14, 1872. Scale of sheet, 400 feet to the inch.

Sheet No. 29′ is a resurvey of a portion of the river after the bridge was built; it shows plan and profile of the bridge and piers, and velocity

and direction of current. This survey was made in 1868. A tracing of this sheet was sent to the Chief of Engineers December 2, 1874. Scale, 200 feet to the inch.

Sheet No. 30 shows 3 miles of river in the vicinity of Hannibal, Mo. This survey was made in 1866, and was intended to cover any possible location of a bridge at this place, authority having been given by act of Congress approved July 25, 1866, to build one here. A tracing of this sheet was sent to the Chief of Engineers February 14, 1872, and another December 2, 1874, to make the set of bridge maps complete. Scale of this sheet is 400 feet to an inch.

Sheet No. 30′ is a map of the river in the vicinity of the railway and highway draw-bridge at Hannibal, Mo., from the survey made in October, 1876. It shows velocity and direction of current, soundings above and below the bridge, approaches to the bridge, arrangements of spans, &c.

Sheet No. 31 is a map of the river in the vicinity of the railway draw-bridge at Louisiana, Mo. It shows the direction and velocity of current, soundings above and below the bridge, the arrangement of spans, and the accessory works built to control and direct the current. The survey was made in October, 1876.

Sheet No. 32 embraces the river from 2 miles above Alton, Ill., down below the mouth of the Missouri River, about 7 miles. It shows the velocity and direction of the current in the Missouri and Mississippi at their junction. This was surveyed in 1868. Scale of this sheet, 400 feet to an inch. A tracing of this sheet was sent to the Chief of Engineers July 25, 1871. A previous survey was made at Alton by my assistant, Maj. H. C. Long, in February and March, 1868. My report on it is dated April 9, 1868, printed in Annual Report of Chief of Engineers for 1868, p. 370. Map accompanied that report, on a scale of 4,000 feet to an inch.

COMPILED MAPS ON A SCALE OF TWO INCHES TO A MILE.

These maps were designed to bring together all the general data we possessed in regard to the Mississippi Valley, from the Falls of Saint Anthony to the junction with the Ohio River, including not only our own surveys, but all others available to us.

Where our own surveys are made, these maps have all the accuracy that can be attained without being supplemented by a geodetic survey. They comprise 22 sheets, continuous along the Mississippi, numbered consecutively from the Falls of Saint Anthony to the Ohio River. The sheets are about 5 feet by 3 feet, backed on cloth. They average about 35 miles to each sheet. They are on the same scale as a continuous series of sheets along the Minnesota and Wisconsin Rivers, prepared by me and already sent to the Chief of Engineers.

Where our own surveys came on these sheets, the outline and number of the sheet of detailed survey are shown. Tracings of the first five, at the upper part, were sent to the Chief of Engineers December 23, 1871; the five at the lower part were sent July 25, 1871, and the others February 14, 1872.

The largest portion of this map was derived from the United States land surveys, but in the outset we met with great difficulty in utilizing them, because of a general absence of connections across the valley from Cairo to Fort Snelling. This difficulty has heretofore largely prevented the use of this material by others, so we early made it part of our surveys to supply connections. This effort we found a much more serious

undertaking than we had supposed. It is well to remind the reader here that the United States land surveys on the east side of the Mississippi were made from meridians on that side, so that the surveys extended westward with their ordinarily increasing errors, and terminated on the Mississippi without any closing check. The same course of surveying was followed on the other side, with the same results. Limited appropriations of money for this work necessitated this, and the United States Land Office is not to be blamed for it. Two sets of accumulated errors were thus brought opposite to each other, without the check of the one upon the other. The actual condition of the maps of the two sides of the Mississippi was therefore such that, when brought together, if a reasonable allowance was made for the average width of the watercourse at one point it would entirely close it up at some places, and in others make it appear to widen into lakes in places where there were no lakes. Along with these obvious errors there were other obstacles to uniting these land-office maps of the two sides. In the upper river there were islands, sometimes 3 miles long, unsurveyed, because of their little value, which only appeared as blanks on the plats.

In the lower course of the river there were changes in the banks of the stream which often, in a few years, were equal to the whole width of the river. Obviously, then, the only tolerably reliable connections were where the banks were determined by the land surveys on both sides at places where the shores were permanent; here a simple triangulation was sufficient, but it was seldom the case that both banks were permanent; or by actual surveys between ascertained corners or points of the United States land surveys on opposite sides. It was surprising to find how difficult it was to find such points, and when found they would require a survey, with chain and transit, over river-bottom often many miles long, in parts impassable. Generally the bluffs or high grounds are too far apart for triangulation, except with large instruments and expensive measurements, which with our means we could not supply, and, consequently, when the lands were overflowed, connections were impracticable to us.

Where our continuous river surveys were made, all the land survey corners that could be found were connected with our survey. Another serious difficulty in attempting to construct the map of the main watercourse from the land surveys arises from the great changes which are taking place in the alluvial banks. The surveys began at the opening of the present century. The opposite shores were surveyed, sometimes many years apart, so that no good representation of the opposite bank would exist at the time either survey was made. But these changes of the river-course have not materially affected the form or position of the high water margins, so that all the land-survey maps, in proportion to their accuracy at the time when made, may be taken now as the position of the banks above overflow.

For the series of 22 sheets we adopted the scale two inches to the mile, because that is the scale of the records in the United States land offices, and any sheet obtained from them can be compared directly. We have not been able to get the dates of the land surveys to put on the map, in many cases, but that can be ascertained in any important case by referring to the records at Washington. We do not claim great exactness in the representation of the river where the land surveys are even partly used, and we have never used them alone. The positions of the bluffs are reliable enough for general purposes. We have added a great deal to this information, even where our detailed surveys did not extend, by examinations to locate bluffs, terraces, and islands, and to

make connections across the valley between the systems of land surveys on the opposite sides, and by the aid of county maps and town plats, railroad surveys, &c. A description of all the connections across the valley used by us is given in another place. It would have been desirable to have more of them. In one or two places we have reason to believe that the error in width across the valley as represented is nearly 2,000 feet, after applying all the checks we have, but this is probably a maximum.

We have put on the map the lines of the United States land surveys, and as a knowledge of the reliability of these positions is useful for many purposes, the following is an account of the nature of the connections made across the river. After this account a number of places are stated, where intermediate connections are desirable for reason of some irregularity in the land surveys. From 3 miles below the Falls of Saint Anthony to Pine Bend the United States land-survey lines are continued across the river, and the townships on both sides are numbered from the same parallel and meridian. In this distance occasional connections were made; one near Meeker's Island, 2 miles below Saint Anthony; again, at Saint Paul, at Newport, at Merrimac, at Pine Bend, where the Wisconsin surveys and the surveys from the Iowa meridian join; at Hastings, at Prescott, and at Trenton, Wisconsin.

A connection had been made across Lake Pekin, near Maiden Rock, by the State of Minnesota, which was used by us. We connected with Minnesota surveys at Wabasha, and near Winona, in Minnesota, and opposite Wabasha, at Alma, at Fountain City, and opposite Winona, in Wisconsin. Between these places our survey was continuous.

The next connection of the two systems is at Trempeleau. From the Falls of Saint Anthony to this place the connections made are probably sufficient. The greater portion of this section of the river was surveyed by us, and no difficulty was found in compiling the intervening parts taken from the land-office plats. From Trempeleau to Brownsville, Minn., where our next connection was made, there is need of two or three reliable connections. In this distance there are irregularities in the land-office surveys that are undetermined; they will probably be found on the Wisconsin side of the river.

In our survey of Coon Slough and Raft Channel, connections were made with the land-office surveys in Wisconsin, opposite Brownsville, and at Bad Axe; also with the Minnesota survey at Brownsville. These connections, with that made by Capt. T. J. Lee and Lieut. J. G. Parke, of the Topographical Engineers, in fixing the boundary between the States of Minnesota and Iowa, are sufficient from Brownsville to the south boundary of Minnesota. From here to Prairie du Chien, Wis., we made no connections. In this distance of about 40 miles it is desirable to have several connections with the land surveys on the opposite sides of the valley.

At Prairie du Chien our survey was connected with the land survey of Wisconsin, but no corners near the river could be found on the opposite side. Here, however, the right or Iowa bank is rocky and not subject to change, so that the land survey agreed very closely with ours, and thus gave us a fair means of connecting. From this point to Dubuque we made no connection. At Dubuque the survey started at the south boundary line of the State of Wisconsin, and was connected with the surveys of Iowa. Connections between Prairie du Chien and Dubuque are needed. From Dubuque to Savanna, about 40 miles, we made no connections. In this distance there is some irregularity in the land surveys not shown on the plats. Between Savanna and Dubuque our map is constructed from the land surveys, which make the river at

Huntsville, about half way between, about 2,000 feet wider than it is. The surveys at Clinton, Iowa, and at the Rock Island Rapids give satisfactory connections at those places. The land surveys near Buffalo, Iowa, were shown on the plats to have been connected, and were adopted by us. At Keithsburg, Ill., connection was made by us, and the width of the river was determined by triangulation. At Burlington, Iowa, our survey of about 4 miles of river was connected with the land surveys of Iowa, but not with those of Illinois. At Fort Madison, Iowa, a connection of the land surveys of Illinois and Iowa was made. It is desirable that other connections of the United States land survey should be made between Rock Island and Fort Madison, but it is believed that no great irregularity exists in them.

Connections were made by the river surveys at Des Moines Rapids. Approximate ones were made by our surveys at Quincy, Ill., and Louisiana, Mo. At Clarksville, Mo.; at Hannibal, Mo.; at Cap au Gris, Mo.; and at Alton, Ill., we made direct connections of the two sides.

The surveys of Saint Louis Harbor gave an approximate connection at that place. Connections were made by us at Kimmswick, Mo., 20 miles below Saint Louis; at Penitentiary Point, Ill., 46 miles below; at Fountain Bluff, 117 miles below; at Cape Girardeau, Mo., 150 miles below; and at Commerce, 165 miles below.

From the mouth of the Missouri to the mouth of the Ohio River the connections made are probably sufficient to give the valley nearly correct; but the low water river cannot be relied upon below Saint Louis, except at the few points where it was measured by us. The main value of this part of the map is in showing the relative positions of the bluffs and the lakes, and other features of the bottom-lands, which are mainly from the United States land surveys thus brought together. The map of the Valley of the Minnesota was made directly from the United States land surveys, mainly by Capt. C. E. Davis, civil engineer, with many notes and additions from personal examination and measurement. Considerable additions to it, and some changes, were afterward made, as described in the report on the Minnesota River. (See annual report of Chief of Engineers for 1875.)

MAP OF THE VALLEY OF THE MINNESOTA AND MISSISSIPPI RIVERS.

This map is a reduction of the maps on a scale of 2 inches to the mile, to one of 1 inch to 6 miles. It serves as an index-map to the maps on a scale of 2 inches to the mile, and has a special interest of its own in bringing the great valley fairly before us in one view, with an approach to accuracy that will require very nice surveys to improve upon this scale. It has been extended both north and south of the limits of the maps on a scale of 2 inches to the mile.

Concerning the northern extension into the valley of the Red River, there is little more to be said than that it is taken from the United States land surveys, with additions of railroads from Colton's map, and such information, confirmatory to our representation, as could be derived from Long's and Nicollet's explorations, and from Stevens's Pacific Railroad exploring expedition. We are indebted, too, for information furnished by Mr. A. J. Hill, of Saint Paul, who is one of the most faithful and accurate of laborers in geographical investigation. Mr. J. Woolworth Colton's maps have also aided us very materially.

In the southern part of the river, about the mouth of the Ohio, and southward, we have taken the map of Humphreys and Abbot (plate II of the Report on the Physics and Hydraulics of the Mississippi River).

To this we have added some information, since obtained, from various sources. Among these we may mention the geological survey of Illinois under Worthen; the geological work upon Kentucky, by D. D. Owen; reconnaissances by General Simpson, United States Engineers, during the war; some of the recent railroad lines, and surveys and notes, furnished by Capt. C. J. Allen, Corps of Engineers.

MAPS COLLECTED USED IN COMPILATION, ETC.

Along with the original maps above enumerated, I send the following maps collected during the conduct of the survey; most of which may be useful for future reference.

In a new country like this the names are very ephemeral, and soon pass out of use, and are not repeated on the later maps. One would be surprised to see how the names used by Long, Nicollet, and other first explorers are disappearing. There are, besides, mushroom towns in the first settlement, that, exercising considerable influence for a time, disappear without a vestige left on the site. It would be well to preserve all these records for future reference, as far as practicable, even after they have ceased to be of practical every-day use in the region to which they relate.

Map of United States. Morse and Gaston, Nassau Street, N. Y., 1856.

Sectional Map of Minnesota. J. S. Sewall, Saint Paul, Minn., 1866.

Township and Sectional Map of Minnesota (6 *sheets*). Power and Thornton, 1867.

Map of Minnesota. Rice and Reed, Saint Paul, Minn., 1870.

Map of Mille Lacs. Frank Cook, C. E., 1869.

United States Land Survey Plats along Mississippi River in Minnesota.

Minnesota Valley Railroad.

Ramsey County, Minnesota. W. F. Duffy, 1859.

Hennepin County, Minnesota. R. Cook, 1860.

Saint Anthony and Minneapolis, Minn. R. and F. Cook, 1861.

Ramsey, Manomin and Hennepin Counties, Minnesota. L. G. Bennett, 1867.

Tracing of Mississippi River near Saint Paul, Minn. Surveyed in 1854–55 by J. S. Sewall, C. E.

Tracing of Mississippi River from Meeker's Island to Saint Paul, Minn., with plan of canal and lock. By J. S. Sewall, C. E., 1868.

Hastings, Minn.

Westervelt, Goodhue County, Minnesota. By Baldwin.

Wabasha, Minn. D. W. Wellman.

Island City, Minn. Bliss & Spear.

Brownsville, Minn. Lithograph by A. Mendall, Chicago, Ill.

Tracings of Saint Paul Highway Bridge, Saint Paul Railway Drawbridge, 1876, made under direction of Maj. F. U. Farquhar, United States Engineers.

Map of Wisconsin. With part of Illinois, Michigan, and Minnesota, by J. Farmer, C. E., Detroit, Mich., published by L. Farmer, Milwaukee, Wis.

United States Land Surveys along the Mississippi River in Wisconsin.

Fountain City, Wis., showing position of sectional corners, 1867.

Buffalo City, Wis.

Trempeleau, Wis.

La Crosse, Wis., tracing of bridge, with current-observations, 1876, made under direction of Colonel Macomb.

La Crosse, Wis. Bliss & Spear, 1859.

La Crosse, Wis. Bliss & Spear, 1859.
Prairie du Chien, Wis. Ira B. Brunson, 1856.
Columbia County, Wis. A. Menges & Co., Madison, Wis.
Green Lake County, Wis. Bogert, Haight & Livermore, 1860.
Dane County, Wis. Menges & Ligowski, Madison, 1861.
United States Land Survey along the Mississippi River in Wisconsin.
Plan of improvement of Dubuque Harbor, 1855 (*sections across river*). Jos. C. Jennings, United States agent.
Mineral Regions in vicinity of Dubuque, Iowa. 1858.
Dubuque County, Iowa. L. H. Thompson, Dundee, Ill., 1866.
Sabula, Jackson County, Iowa. Printed map, no date.
Clinton County, Iowa, 1865. M. H. Thompson & Bro., Dundee, Ill.
Clinton, Iowa, 1855.
United States Land Surveys along the Mississippi River, in Illinois.
Leopold Richter's Map of Illinois, 1861. Springfield, Ill.
Scott County, Iowa, and Rock Island County, Illinois. Thompson & Everts, Geneva, Ill., 1868.
Tracing of a portion of Survey of Rock River, Illinois, from mouth up to Lyndon, made by General J. H. Wilson, in 1866.
Hancock County, Illinois. Holmes & Arnold, Buffalo, N. Y., 1859.
Pike County, Illinois. Holmes & Arnold, Buffalo, N. Y., 1860.
Sny Carte Bottom, with profile, Adams, Pike, and Calhoun Counties, Illinois, by Leonard.
Alton, Ill. Hart & Mapother, N. Y., 1854.
Madison County, Illinois. Holmes & Arnold, Buffalo, N. Y., 1861.
Saint Clair County, Illinois. J. H. Holmes, 1863.
Chester, Ill. Jos. Noel, 1857.
Cairo, Ill. H. C. Long, C. E., 1850.
Cairo, Ill., November, 1855.
United States Land Surveys along the Mississippi River, in Missouri.
Tracing of a portion of Hannibal, Mo. With United States land survey connection, 1867.
Tracing of Hannibal Bridge, 1876 (showing railroad approaches to bridge), by division engineer of T. W. W. R. R.
Louisiana, Pike County, Missouri. John B. Woods, city engineer, 1866.
Tracing of the bridge site at Louisiana, Mo. (with contours of bottom of river), by E. L. Corthel, chief engineer.
Lincoln County, Missouri, by A. R. Finley, published by E. J. Ellis, 1860.
Tracing of the mouth of Missouri River. Survey for city of Saint Louis by Col. W. E. Merrill, in 1868–'69.
Tracing of the Mississippi at mouth of the Missouri River, showing banks in 1861 and 1868, made for Saint Louis, by J. G. Joyce & Bischoff.
Saint Louis and Saint Charles Counties Missouri; Madison and Saint Clair Counties, Illinois. L. Gast and Bro., Saint Louis, Mo., 1851.
Saint Louis, Mo. Jules Hutawa, Saint Louis, Mo.
Wolf Island in Mississippi River, near Columbus, with calculations of quantity of water in each channel in 1843.
Tracings of Swamp Lands in Missouri and Northeastern Arkansas.

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Diagram 1, in 5 sheets.

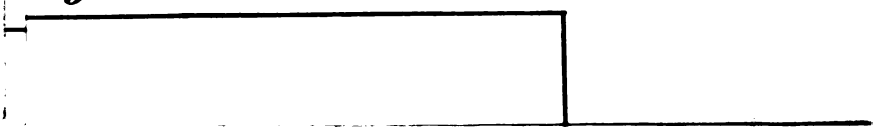

Diagram 1, *in 5 sheets.*

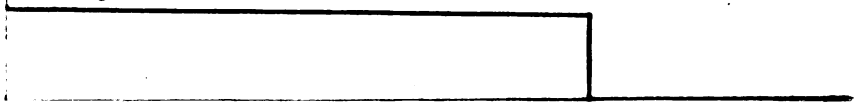

Diagram 1, in 5 sheets.

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n 1, in 5 sheets.

Diagram 2, in 2 sheets.

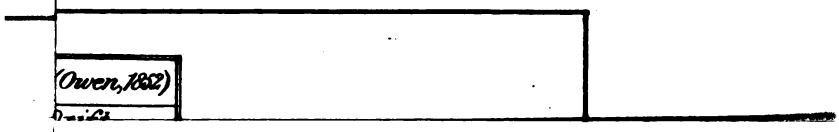
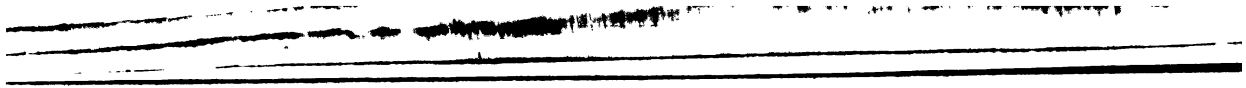


Diagram 2, in 2 sheets.



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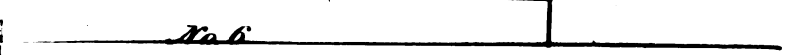

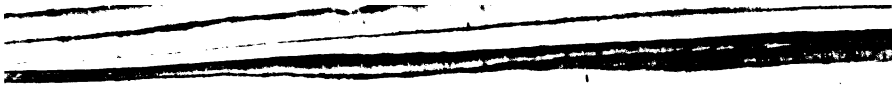

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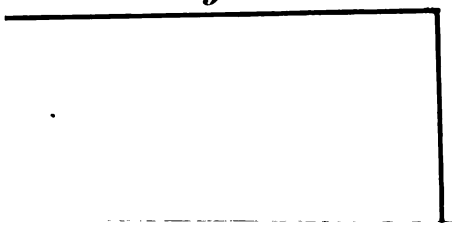

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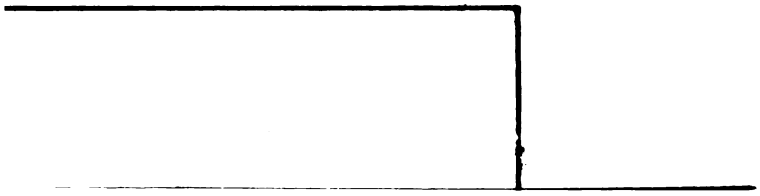

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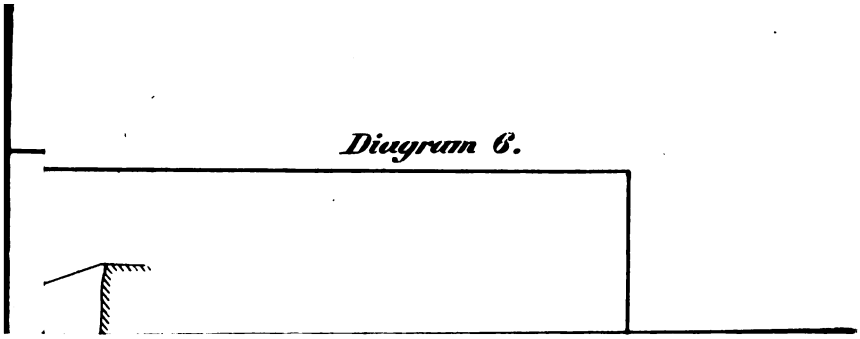

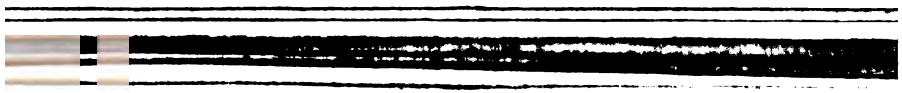

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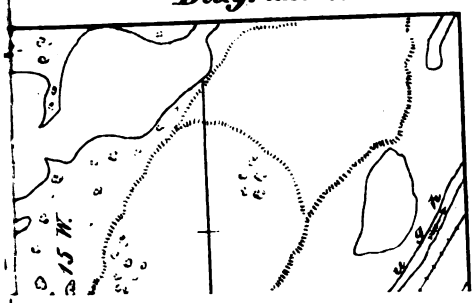

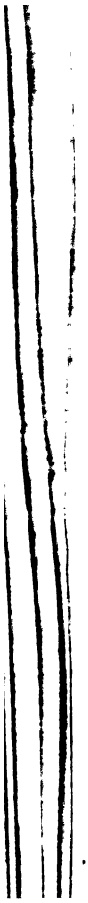

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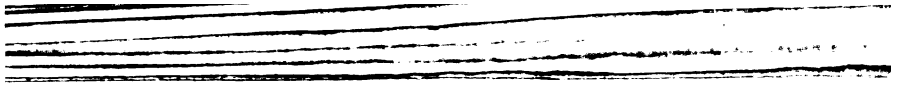

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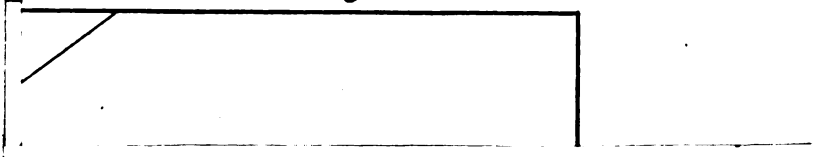

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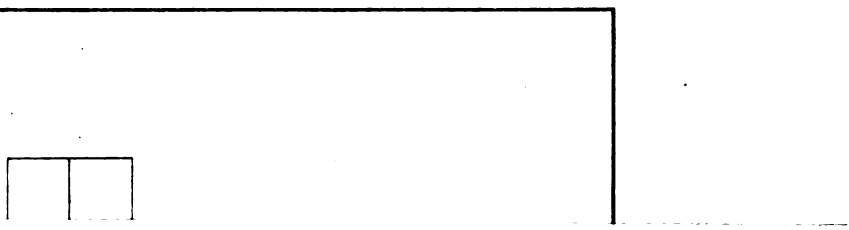
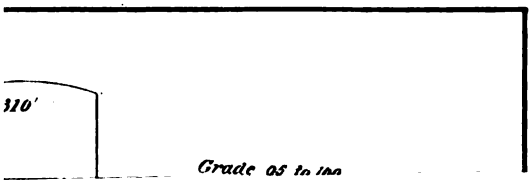


Diagram 11.

Diagram 12.



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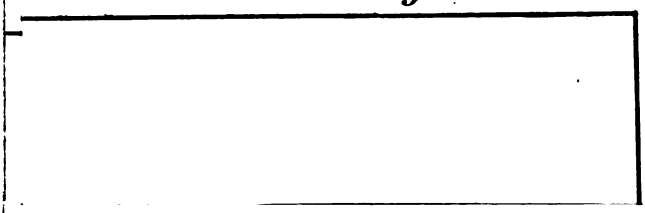

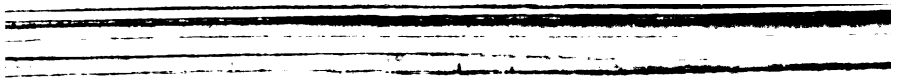

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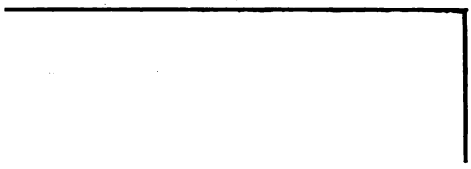

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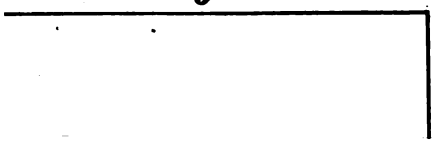

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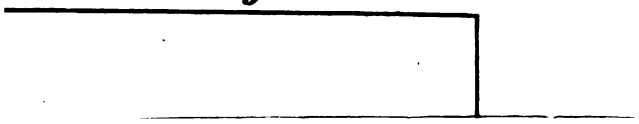

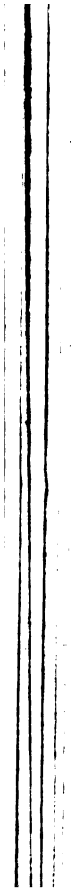

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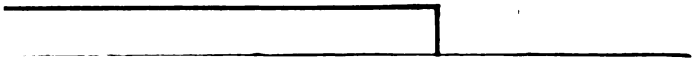

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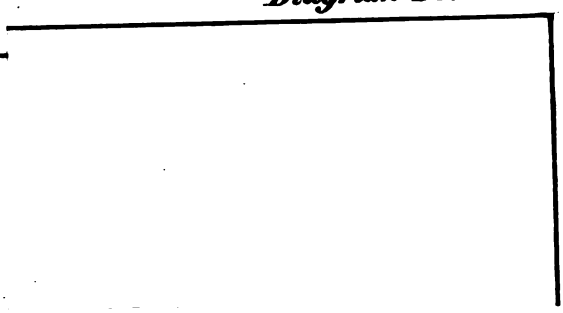

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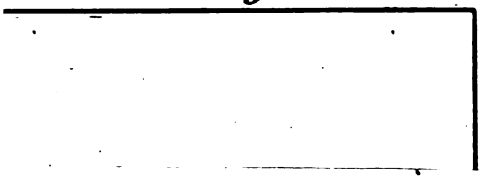

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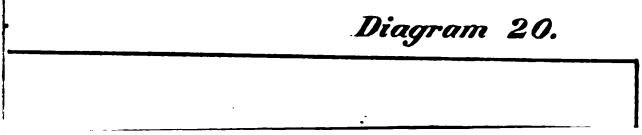

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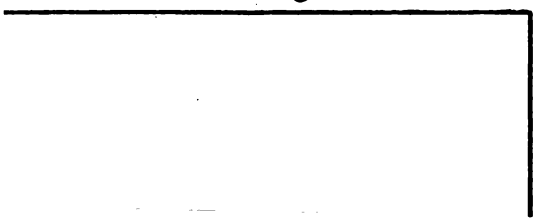

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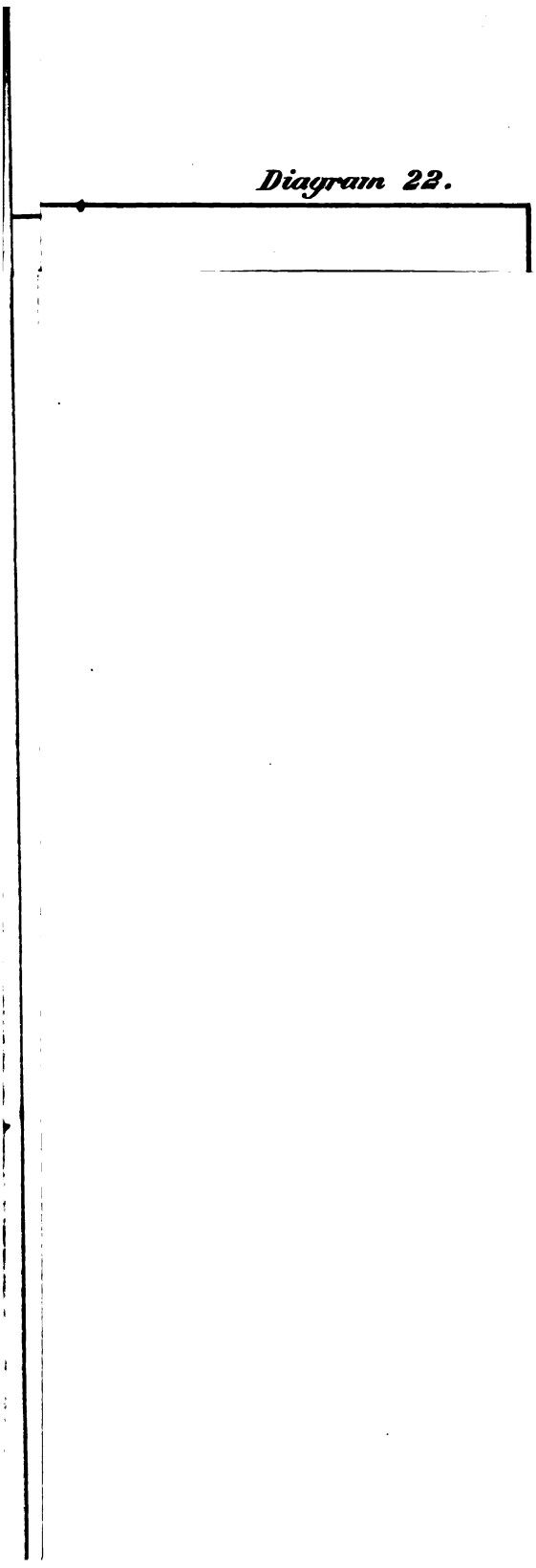

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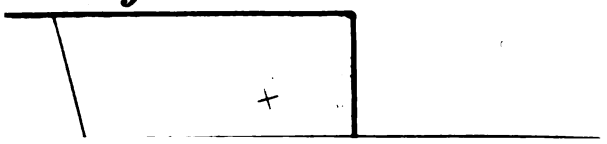

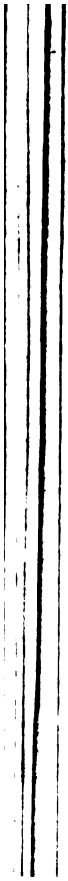

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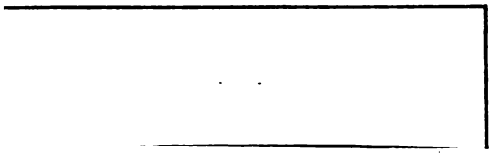

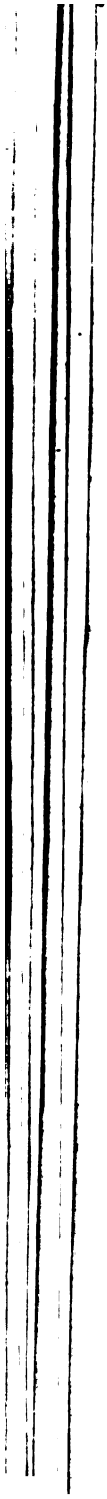

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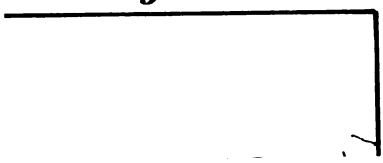

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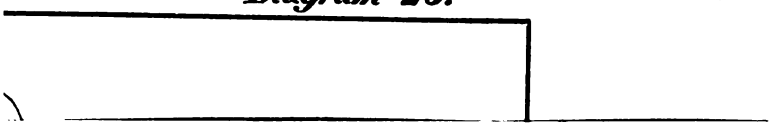

Diagram 27.

Diagram 28.
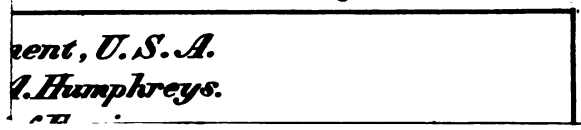
Diagram 29.